NICK KANAS

HUMANS IN SPACE

The Psychological Hurdles

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Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

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San Francisco, CA, USA

SPRINGER-PRAXIS BOOKS IN SPACE EXPLORATION

Springer Praxis Books
ISBN 978-3-319-18868-3 ISBN 978-3-319-18869-0 (eBook)
DOI 10.1007/978-3-319-18869-0

Library of Congress Control Number: 2015940882

Springer Cham Heidelberg New York Dordrecht London

(Front cover and spine): "Working in space can be an isolating experience. Here a Space Shuttle astronaut tests a safety system during an EVA and is perhaps in a thoughtful frame of mind like that expressed by his imaginary companion. Image of astronaut taken from a NASA/JSC digital image dated 16 September 1994; human face and image of Earth taken from Shutterstock."
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(Back cover, right): "Teamwork is important for space activities. Here, two astronauts prepare to egress from a Space Shuttle for a joint EVA. NASA/JSC digital image dated 9 February 1995."

Cover design: Jim Wilkie

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

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Acknowledgments

I have always been a "space cadet." Going back to my pre-teen years, I devoured science-fiction books and observed the heavens as an amateur astronomer through my small telescope. As a medical student at the University of California, Los Angeles, School of Medicine, I spent the summer of 1968 working in a NASA-funded sleep research project and the summer of 1969 as a teaching assistant to undergraduates participating in a summer space biology program (where I got to experience several G's on a centrifuge during a field trip to the Ames Research Center and watched the first lunar landing on live television with several of my students). In the fall of 1970, I worked on a special project at the Johnson Space Center. My supervisor, psychologist Bill Feddersen, showed me the ropes, including a chance to experience depressurization in an altitude chamber and periods of weightlessness on the "vomit comet" airplane with an Apollo crew practicing a space procedure. The result of my project was a NASA Technical Memorandum that I wrote with Bill that was published in 1971 and entitled *Behavioral, Psychiatric and Sociological Problems of Long-Duration Space Missions* (N. Kanas and W. Feddersen, NASA TM X-58067, National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas). This monograph formed the nucleus of many of my subsequent writings and informed me about important issues that I would later use in my research activities, and I will always be grateful to Bill for this important start in my space-related career.

Prior to the 1990s, NASA was not soliciting psychological studies from extramural sources, but I was fortunate in being invited by Alan Kelly to help him prepare the findings of his Stanford University master's thesis for publication. The study investigated the communication patterns of astronauts and cosmonauts, and the results ultimately were published by peer-reviewed journals in 1992, 1993, and 1994. I am grateful to Alan for involving me in this project. I also was invited to contribute a psychological study for a 135-day space simulation activity sponsored by the European Space Agency (ESA) that was called HUBES, or the HUman BEhaviour Study. My results were published in 1996.

In the early 1990s, NASA decided to solicit psychological studies in preparation for its participation on the International Space Station and Mir. My colleagues at the University of California, San Francisco, and I were awarded two large NASA research grants from

1995 to 2006 that funded empirical work on the psychology and interpersonal interactions of astronauts and cosmonauts in space. I was the Principal Investigator for these two projects, and my team included both American personnel at the University of California, San Francisco, and one of its affiliates, the San Francisco Department of Veterans Affairs Medical Center (the location of my lab). We collaborated with Russian co-investigators at the Institute for Biomedical Problems (IBMP) in Moscow. Our team also was funded by NASA and the National Space Biomedical Research Institute (NSBRI) from 2006 to 2010 to study crewmember autonomy in three space simulation environments on Earth.

These various activities form the core of the information in this book, and I am grateful to my various research colleagues, without whom it could not have been written. On the American side, they are: Pamela Baskin, Alan Bostrom, Jennifer E. Boyd, Ellen M. Grund, Eva C. Ihle, Charles R. Marmar, Thomas Neylan, Stephanie A. Saylor, and Daniel S. Weiss. On the Russian side, they are Vadim I. Gushin, Olga P. Kozerenko, Vyacheslav P. Salnitskiy, and Alexander Sled. Dietrich Manzey (who co-wrote the text book *Space Psychology and Psychiatry* with me), Gro Sandal, and Peter Suedfeld also have been helpful collaborators. Many people working at NASA, ESA, the IBMP and the Russian Federal Space Agency, and the NSBRI also have been supportive on these various projects, and I am grateful for their financial and operational assistance throughout the years. I especially would like to thank Jennifer Boyd, Walt Sipes, and Steve Vander Ark who provided helpful comments to an earlier draft of this book.

Finally, I am grateful to my wife Carolynn, who for over 40 years has supported me in my various space-related projects, many funded and some unfunded. She has accompanied me to some conferences and held the home front while I was away at other conferences or training research subjects in Houston, Moscow, or Europe. Her involvement with this book has been indirect but nevertheless very important.

Preface

With the continued use of the International Space Station, the construction of rockets and space habitats aimed at sending humans to Mars, the advent of space tourism, and the increasing involvement of private enterprise in on-orbit activities, there has been renewed interest in space. This interest has prompted us to look at the impact of space missions on the human psyche and on the interpersonal interactions of the humans on board (both crewmembers and tourists). Using anecdotal reports from astronauts and cosmonauts (the Russian term for their astronauts), and the results from studies conducted in space analog environments on Earth (e.g., the Antarctic, submarines, space vehicle simulators) and during actual missions on orbit, *Humans in Space*: *The Psychological Hurdles* broadly reviews the various psychosocial issues that affect space travelers. These issues not only are discussed with reference to astronauts working today in space, but they also are considered in terms of future travelers such as space tourists, crewmembers going on expeditions to Mars and other planets in the Solar System, and humans who may someday be involved in multigenerational missions to exoplanets around distant stars.

The book is divided into two sections. The first deals with near-Earth missions orbiting our planet or traveling to the Moon and back. Because these missions have actually occurred, what is presented reflects actual reports from space and research conducted in both space and analog environments. The eight chapters in this section deal with psychosocial stressors; psychological, psychiatric, and interpersonal issues; the effects of cultural and language differences; positive effects of space travel; space tourism; and countermeasures for dealing with the psychosocial aspects of the space environment. The second section takes what we know and extrapolates it for future interplanetary and interstellar missions. Its four chapters deal with the effects of increasing autonomy, expeditions to Mars and to the outer Solar System, and interstellar missions. An epilogue sums up the main issues from a psychological perspective.

Humans in Space: *The Psychological Hurdles* is targeted for the general public. It is meant to be of interest to space enthusiasts, workers in space and aviation professions and businesses, amateur astronomers, science-fiction readers, people interested in space advocacy, employees at space agencies and in isolated and confined environments on Earth,

and members of the general public who are interested in space travel and the human side of long-duration space missions. Other targeted audiences include students and professors in university psychology, social science, and medical programs; and psychologists, physicians, astronomers, and other scientists interested in human space travel. The psychological hurdles are meant to be identified and jumped over as our experiences in space develop and psychosocial problems are resolved. Let's begin the journey!

San Francisco, CA Nick Kanas, M.D
February 10, 2015

Abbreviations

CO_2	Carbon dioxide
CRM	Crew Resource Management
CSA	Canadian Space Agency
Desert RATS	Desert Research and Technology Studies
ESA	European Space Agency
EVA	Extravehicular activity
EXEMSI	Experimental Campaign for the European Manned Space Infrastructure
FKA	Russian Federal Space Agency
FAA	Federal Aviation Administration (USA)
FIRO-B	Fundamental Interpersonal Relations Orientation–Behavior
GES	Group Environment Scale
HMP	Haughton-Mars Project
HTO	Horizontal take-off
HUBES	HUman BEhaviour Study
IBMP	Institute for Biomedical Problems
ICE(s)	Isolated and Confined Environment(s)
ISEMSI	Isolation Study for European Manned Space Infrastructure
JSC	Johnson Space Center
LOFT	Line-oriented flight training
MARS 500	500-day Mars simulation project
MRAB	MiniCog Rapid Assessment Battery
NASA	National Aeronautics and Space Administration
NASDA	Japanese National Space Development Agency
NEEMO	NASA Extreme Environment Mission Operations program
NSBRI	National Space Biomedical Research Institute
PCVQ	Portraits of Crew Values Questionnaire
POMS	Profile of Mood States
PSPA	Personal Self-Perception and Attitudes test
RAIR	Ram-Augmented Interstellar Rocket

RKA	Russian Federal Space Agency
RLV	Reusable launch vehicle
SFINCSS	Simulation of a Flight of International Crew on Space Station
SFRM	Space Flight Resource Management
sRLV	Suborbital Reusable Launch Vehicle
VIIP	Visual impairment and elevated intracranial pressure
VTO	Vertical take-off
WES	Work Environment Scale
WinSCAT	Spaceflight Cognitive Assessment Tool for Windows

Section I

Near-Earth On-Orbit and Lunar Missions

1

Psychosocial Stressors in Space and in Space Analogs

With the occupation of the International Space Station (ISS) and plans being discussed for sending expeditions to Mars and other Solar System bodies, humans are committing themselves to a continuing presence in space. Such missions will be many months to years long, and the notion of establishing permanent colonies is being considered. But these plans offer a number of challenges. This chapter will review some of these challenges, with particular reference to long-duration manned space missions.

1.1 STRESSORS IN SPACE

A stressor is a physical, psychological or interpersonal characteristic of the environment that impacts on someone. Sometimes, stressors are hyperarousing (e.g., fire, loud noises); other times, they are hypoarousing (e.g., isolation, darkness). Examples of physical stressors that are found in space or in space vehicles and habitats include:

- periods of high acceleration;
- microgravity;
- ionizing radiation;
- meteoroid impacts;
- light/dark cycles;
- vibration;
- ambient noise;
- low and high temperature;
- diminished lighting;
- no air or poor air quality.

Some of these stressors may lead to others. For example, the absence of air and low temperatures necessitate oxygen generators and heaters that can be quite noisy and lead to increased vibration in the environment. These are engineering givens, and the best that can be done is to minimize their intensity.

A unique stressor is microgravity, which can be eliminated by some sort of artificial gravity system. For example, a habitat in space can be accelerated with a force equal to

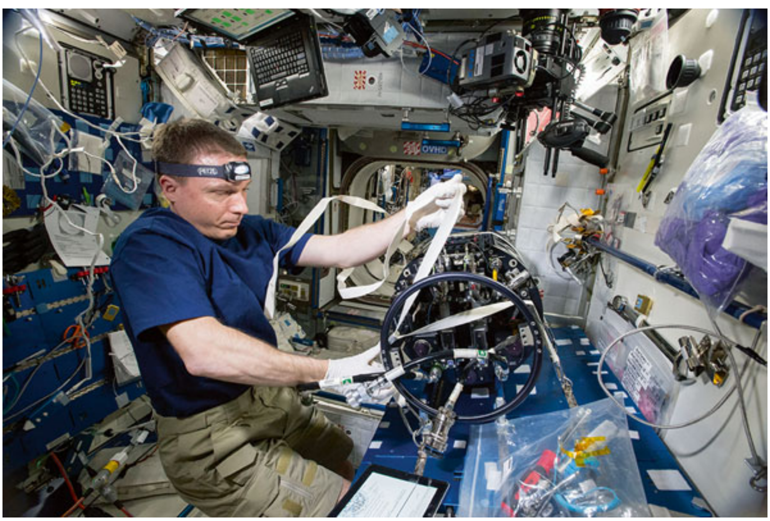
N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_1

one Earth gravity (1 *g*), or the crew may be housed in a giant wheel that revolves around a core with a speed whose centrifugal force produces a 1 *g* gravity. However, these artificial gravity solutions come with high engineering downsides and may even produce their own stressors, such as inner-ear disturbances due to Coriolis forces from a rotating wheel habitat.

In addition, there are a number of psychological stressors related to manned space missions, and these will be the focus of this book. Some psychological stressors include:

- isolation and confinement;
- life-threatening danger;
- periods of monotony versus high workload;
- time effects;
- personality and crewmember-selection issues;
- too much free time;
- increased autonomy;
- dependence on machines and local resources.

Isolation and confinement are characteristic of space missions and force crewmembers to live together in a small space far away from home (Fig. 1.1). A lurking awareness of danger is also part of a mission in the hostile environment of space, whether from a micrometeoroid impact, a malfunction in an important piece of equipment, a fire, or any number of other factors. Periods of monotony can occur, and these can alternate with periods of high workload, such as during spacewalks and emergencies.



1.1 NASA astronaut preparing a combustion apparatus in order to conduct a flame extinguishment experiment on-board the International Space Station (ISS). Even in this large facility, space is tight, and crewmembers must work under confined conditions. NASA image dated May 13, 2015

In missions lasting 6 weeks or more, time effects have been reported. Based on his review of Antarctic and submarine missions, Rohrer [1] has proposed that people working in isolated and confined environments (ICEs) go through three stages: an initial stage of hyperarousal as they adapt to the new environment (which can produce anxiety), a long middle phase where things become routine and monotonous (which can produce depression and homesickness), and a final stage of euphoria as individuals anticipate their return home (which can produce hyperemotional and even aggressive outbursts). Bechtel and Berning [2] view the midpoint of ICE missions to be important (see Sect. 2.2). The idea is that some crewmembers arrive at this milestone with a sense of relief, but then realize that there is still another half of the mission to go before they can return home. This results in psychological dysphoria (such as depression or homesickness) as well as interpersonal problems, which Bechtel and Berning have called the "third quarter phenomenon." But, as we shall see later, not every person working in an ICE experiences this effect to a measurable degree, and some people even feel energized knowing that they are on the down slope of their journey.

Personality issues also are important. What constitutes the "right stuff" for a person on a long-duration space mission may be different from that which is important for someone on a short-term mission. Long-term space travelers need to be selected who not only are comfortable working alone on a project for a focused period of time, but who also are able to interact with fellow travelers during social events and meal times [3]. In addition, not everyone in the astronaut corps will volunteer to be away from family and friends for a multi-year mission, so this may skew the selection process to specific types of individuals (e.g., single people or people without small children). At any rate, expeditionary crewmembers or space colonists will have a great deal of free time on their hands, and they must find ways to deal with the lack of structure. Hobbies and diversions also can change over time, so the space habitat needs to have a number of resources to address these changing interests.

Crewmembers on expeditionary missions to the planets will have a great deal of autonomy and must be equipped to deal with routine and emergency occurrences on their own, since evacuation to Earth will be less likely than on an on-orbit mission. In addition, crewmembers will be heavily dependent on their computers and other machines for basic life support and other operational activities. The psychology of this dependence and the ergonomic characteristics of the human-machine interface are important issues to be considered in designing space vehicles and habitats. Since not all supplies and fuel can be brought with them, crewmembers also will need to depend on local resources available to them to chemically generate food, water, and fuel. So again, the ease of use and reliability of the relevant equipment will be important.

Interpersonal stressors related to long-duration space missions are:

- group size;
- limited social contacts and novelty;
- group heterogeneity;
- common language;
- cultural differences;
- governance structure;
- leadership roles.

One factor concerns the number of crewmembers. In studies of unstructured groups on Earth, it has been shown that odd-numbered groups form a consensus better than even-numbered groups, since a majority usually can be created [4]. In addition, in larger groups, people can find at least one person with similar interests who can help them deal with feelings of isolation, and this helps in building cohesiveness.

Crew heterogeneity also is important. Future space missions likely will involve people of both sexes, different national backgrounds, and varied life experiences. Diversity can be stressful, especially initially as crewmembers adjust to one another. People from different cultural groups may misinterpret subtle behavioral nuances. For example, Americans and Northern Europeans might interpret the gesticulations and interpersonal space closeness from a Southern European or Arabic colleague as hostility or aggression rather than simply reflecting a cultural norm. But interpersonal diversity can bring a wider range of resources to bear in dealing with a problem and can be beneficial later in a mission as people begin to tire of the routine and look for novelty and new experiences. One important factor in bringing people together is speaking a common language. This improves bonding through the understanding of nuances behind discussions and jokes, and it may help the group deal more efficiently with emergencies when quick action is necessary.

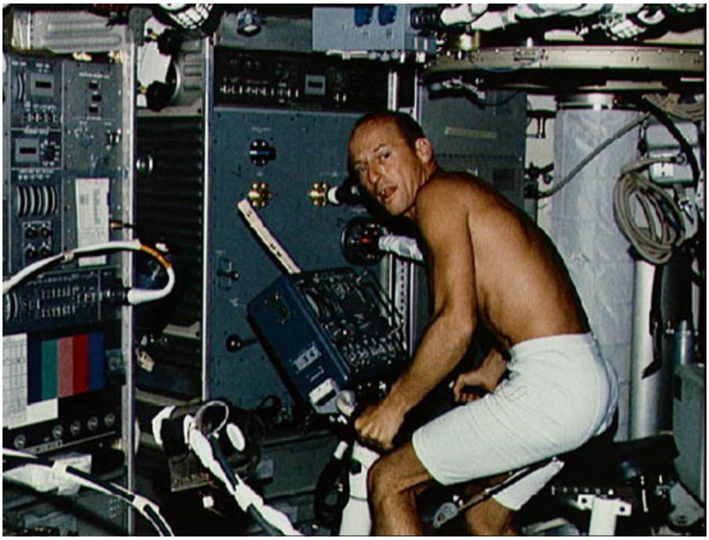
The group governance structure also can be stressful, especially if it is too authoritarian in nature. However, a loose laissez-faire structure is not good either, since it is difficult for an isolated group of people to discipline themselves, especially if food, water, and other resources are limited and rationing becomes necessary. Leadership in the group can make a big difference. Studies of isolated groups have suggested two major leadership roles: the task role, which deals with setting goals and getting the work done; and the support role, which relates to addressing group morale and nurturing people who are having problems [3]. These aspects of leadership become important at different times during the mission. For example, during emergencies, the task role is crucial, whereas during boring monotonous periods, the support role becomes more relevant.

1.2 STRESS IN SPACE

Stress refers to the effects of stressors on someone. Stress in space can be toxic, but it can also be growth-enhancing (i.e., salutogenic). The intensity of a stressor is important. We all need some physical and interpersonal stimulation, but too much or too little is not good for our well-being. Space stress can be categorized in five ways: physiological, psychophysiological, psychological, psychiatric, and interpersonal.

A major factor producing physiological stress is microgravity, the near-zero gravity condition found in space (Fig. 1.2). Many systems are affected, and at times disorders in one system can affect others. In addition, a general disruption in body functioning can itself produce psychological malaise and dysphoria. Examples of the effects of microgravity on the body include:

- space adaptation syndrome (motion sickness);
- bone loss;
- muscle atrophy;
- fluid shifts and their sequelae (e.g., cardiac, renal);
- vestibular problems;
- lowered immune response.



1.2 Bone loss and muscle atrophy commonly occur in microgravity, which produces a nearly weightless state. To slow down this process in space, it is important for crewmembers to exercise, such as on this bicycle ergometer used on the Skylab 2 space station. NASA/JSC digital image dated June 1, 1973

Psychophysiological stress in space relates to the impact of microgravity on the brain, although other factors such as isolation and confinement, atmospheric gases, ambient noise, and light levels can also play a role. Psychophysiological stress will be discussed further in the next section. Psychological, psychiatric, and interpersonal stresses are all central to this book and for this reason will be discussed extensively in the next three chapters.

1.3 PSYCHOPHYSIOLOGICAL STRESS

Microgravity can directly affect the central nervous system as it does other organ systems, especially the brain, and this can also lead to performance problems and psychological changes in space travelers. Some of these psychophysiological stresses include:

- Sleep loss and changes in sleep patterns;
- Disruptions in circadian rhythm;
- Impairments in time sense;
- Increased auditory and visual perceptual sensitivity;
- Disturbances in spatial orientation;
- Attention lapses;
- Confusion;
- Memory problems;
- Psychomotor problems.

Other factors may play a contributing role in producing these effects, such as CO_2 levels in the atmosphere, lighting and noise in the space habitat, fatigue, and workload.

Anecdotal reports and objective studies show that the sleep of astronauts and cosmonauts in space is shorter, more disturbed, and often shallower than is the case for them on Earth [3]. For example, in one study by Barger, Czeisler, and their team [5] involving 64 Space Shuttle astronauts and 21 ISS astronauts, the subjects slept about 6 h a night in space as compared with nearly 7 h after returning to Earth, and over 75 % of the astronauts took sleep-promoting medications during their mission. Although sleep disruptions may be due to external factors (e.g., uncomfortable ambient temperature, high noise levels, space motion sickness, intense scheduling demands), microgravity per se also may play a role. Sleep difficulties are important for mission success. For example, in a study of 28 Mir space station cosmonauts, Nechaev [6] found a correlation between the occurrence of operational errors and deviations in the usual sleep–wake cycle.

It also is important to maintain proper circadian rhythms in space. On Earth, many bodily functions vary in intensity in a 24-h cycle that is regulated by natural or artificial light and darkness. During on-orbit space missions, light is an important zeitgeber that is used to synchronize circadian rhythms with a work/rest cycle set at 24 h to match that on Earth (and usually linked to the day/night cycle in the home of Mission Control). Studies from space have shown that such entrainment generally is successful in preventing a physiologically harmful "free run" of these rhythms [3]. Simulation studies conducted on Earth using a Mars-like scenario have revealed the challenges humans have in maintaining circadian and sleep stability under altered circadian conditions and the need to help crewmembers learn methods of entrainment during such future expeditionary missions [7, 8].

Since the early days of space travel, there have been reports of cognitive disturbances during on-orbit missions, the so-called "space stupids" or "space fog" [3, 9, 10]. These have included impairments in time sense, increased auditory and visual perceptual sensitivity (sometimes leading to illusions), spatial disorientation, lapses of attention and concentration, confusion, memory problems, and impairments in psychomotor ability. Most of these disturbances have been reported early in the mission as the space traveler adjusts to the novelty of being on orbit.

Reviews of cognitive studies from space have suggested that astronauts learn to adjust to the conditions of space, even in missions lasting three weeks or more [3, 10]. This may be due to simple physiological adaptation to the space environment or to the establishment of effective compensatory mechanisms. Although many cognitive studies suffer from small numbers of subjects and show a great deal of inter-individual variability, some generalizations can be made. Sensory and motor adaptations to space can be made, but some people continue to experience a lengthening of time perception, motor slowing, and increased motor variability, even after a month. Increased perceptual sensitivity may be related to asthenia (see Sect. 2.4). Reaction time typically is unaffected. Dual-task/divided attention skills, however, may continue to be disturbed and lead to behavioral deficits. Memory function and learning ability generally remain intact, although more research needs to be done in the area of long-term memory. Executive and higher cognitive functions are good for non-emotional stimuli, but some studies have found deficits with personally relevant and emotionally charged stimuli.

One area needing further clarification concerns a possible relationship between ocular changes, visual impairment, and elevated intracranial pressure (the "VIIP" phenomenon), which can affect some 70 % of returning ISS astronauts [10, 11]. Microgravity has been implicated as an important causal agent, but other factors also may be related (e.g., increased levels of spacecraft CO_2, heavy resistive exercise, high-sodium diet) [12]. The potential impact of this phenomenon on health and cognitive functioning needs to be examined in future studies.

1.4 EXPERIMENTAL EVIDENCE: SPACE ANALOGS VERSUS ACTUAL SPACE STUDIES

Before we discuss some of the psychological, psychiatric, and interpersonal stresses that are found in human space travel, let's examine the kind of evidence that informs us about some of these effects. In general, there are three sources of information: anecdotal reports from people who have been in space, studies from space analog environments on Earth, and research performed during actual space missions.

1.4.1 Anecdotal Reports from People Who Have Flown in Space

Sources of anecdotal reports from people who have been in space are:

- space agency documents from debriefings;
- surveys of astronauts and cosmonauts;
- publications of diaries kept while in space;
- interviews from newspapers and magazines;
- books written by space travelers;
- books written by others (flight surgeons, scientists).

Since they are anecdotal, such sources are subjective and may be biased or skewed. However, since they reflect the feelings and thoughts of space travelers, they also can give us a vivid picture of what it is like to live and work in space. For this reason, anecdotal reports are good places to start in developing ideas and hypotheses for more formal studies.

1.4.2 Space Analog and Simulation Studies

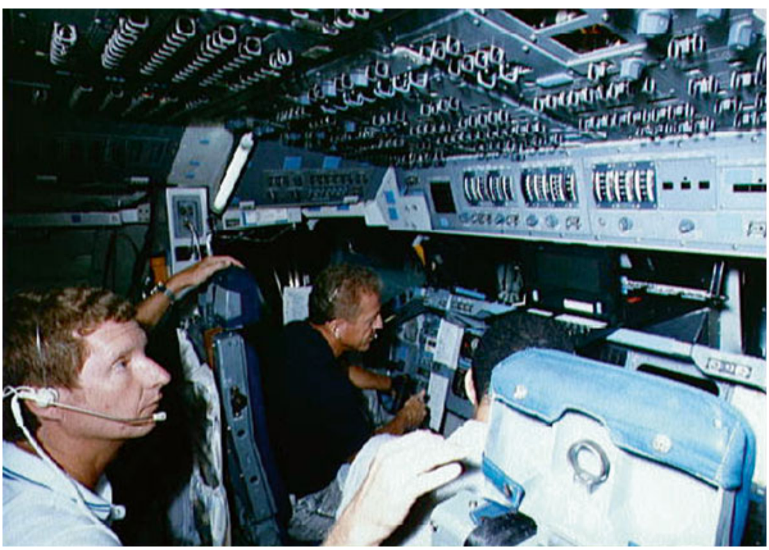
A second source of information concerning the possible impact of the space environment on humans comes from ICEs on Earth. These settings may have many features in common with those that are characteristic of space. Analog studies usually are more naturalistic, so confounding variables may not be controlled, whereas in simulation environments, one usually manipulates variables to make the experience as similar as possible to an actual space mission. Examples of different kinds of space analog and simulation settings include:

- Arctic and Antarctic bases;
- submarines;
- ships at sea;

- land-based confined simulation habitats;
- land-based open but isolated simulation habitats;
- undersea isolated simulation habitats;
- remote sea-based oil-drilling platforms;
- large water tanks;
- high mountains;
- prisons;
- aircraft cockpit simulators;
- hypodynamia (i.e., enforced bed rest) settings.

Some Earth-bound simulators that faithfully reproduce conditions found in space are useful for pre-launch training. For example, astronauts often train suited up in large water tanks to get a feeling for working under weightless conditions. In addition, specific areas of space vehicles may be faithfully reproduced on Earth so that crewmembers can practice simulated activities prior to launch (Fig. 1.3).

Other simulators are useful for activities related to lunar or planetary destinations. For example, the Desert Research and Technology Studies (Desert RATS) missions have been conducted for 2–3 week periods every year since 1997 in the San Francisco Volcanic Field north of Flagstaff, Arizona [13]. Unlike land-based isolated and confined simulation habitats (such as was used in the MARS 500 Project, described in Sect. 10.2), Desert RATS uses a land-based open but isolated simulation setting, although the crewmembers spend much of their time traveling in two-person vehicles meant to represent rovers exploring the lunar surface. A number of operational, geological, and human factor issues have been studied during these missions. In terms of human factors, for example, one study during



1.3 Crewmembers training on the Space Shuttle flight deck simulator at Johnson Space Center. In this way, they are able to become familiar with the actual equipment and practice mission-relevant activities prior to launch. NASA/JSC digital image dated July 14, 1988

the 2010 mission explored a number of interpersonal issues involving teams of scientists and pilots/engineers [14], and another study conducted a sociometric analysis of the communication patterns between the components of the social network (e.g., ground control and flight teams) [15].

What are the pros and cons of space analog and simulation missions in terms of their usefulness for actual space missions? In terms of the pros, space activities are expensive, high-danger, and complicated, and involve just a few people at a time. For research or engineering enterprises that are new or experimental, testing them first on the ground is safer and more economical than testing them in space. Also, more variables can be controlled in simulators than in space, where mission-related operational considerations are given precedence. Many studies depend on large sample sizes to statistically test effects, and these can be achieved more easily in ground-based settings using non-astronaut subjects. Kanas [16] has discussed ways in which analog and simulation environments contribute to the study of a number of psychosocial issues, including social and cultural factors, career motivation, monotony and reduced activity, leadership roles and authority, and the relationship between crewmembers and ground personnel.

In terms of cons, no analog or simulation environment can completely reproduce the environment of space. For example, no space-like environment on Earth can produce microgravity for extended periods of time, and many fail to include isolation, confinement, and true danger. In addition, the excitement of being in space is lacking in land-based simulations.

Some analog environments are more similar to actual space missions than others. Sells [17] outlined 56 factors that he felt were characteristic of long-duration space missions, and he rated 11 social systems to see how they measured up in terms of having these factors. Unfortunately, realistic land-based simulators and non-submarine submersibles were not included in his sample. But, based on his survey, he concluded that submarines and polar environments were the most similar to actual space missions.

Suedfeld [18] has argued that, for psychosocial studies, it is not the physical environment per se that is important, but the psychological meaning of that environment. Sandal et al. [19] echoed this notion in an analysis they performed of a number of simulation studies. They found differences between studies conducted in land-based hyperbaric chambers, where there was no real danger and easy evacuation potential, versus polar environments, where danger and true isolation existed. People working in the former environments experienced low overall anxiety and steadily decreasing levels of anxiety over time, whereas people in the latter showed higher levels of anxiety, especially in the first and third quarters of the mission.

Bishop [20] has outlined four critical psychosocial areas related to space travel that can be studied in space analog and simulation ICEs on Earth. The first is crewmember selection. Space simulators allow us to investigate the impact of various individual and group characteristics on work and leisure time activity in order to determine proper select-in requirements for composing a space crew (see Sect. 2.1.2). The second important psychosocial area relates to the impact of moderator variables on humans living in ICEs. For example, how important is the difficulty in rescuing an injured or impaired crewmember to the psychology of people working in such environments? This can be tested in a space analog setting such as an Antarctic base during the winter-over period, where rescue is improbable due to poor weather conditions. A third critical psychosocial area relates to basic group interactions and processes that produce group fusion (e.g., cohesion) and

group fission (e.g., conflict). These can be studied in simulators by manipulating factors such as group composition, work schedules, privacy conditions, group communication frequency, and leadership styles. Lastly, individual and group performance can be studied by varying factors such as those listed above to see how they impact on the ability of a crew to accomplish mission goals.

1.4.3 Research Studies from Space

Studies conducted during actual space missions represent the third source of information on important psychological, psychiatric, and interpersonal issues affecting astronauts and cosmonauts. The ISS is an especially good platform for such research. Crews often remain in space for months at time, allowing the study of long-term effects of isolation and confinement under actual space conditions. Research supplies can be sent up from Earth, and data can be sent down on returning vehicles. Crews communicate frequently with Mission Control personnel and family and friends on Earth, allowing an examination of crew-ground interactions. Over time, a number of crewmembers can be studied who have worked in the same environment, allowing better statistical power as the number of subjects increases.

In preparing for a Mars expedition, the ISS could be turned into a simulator of the outbound and return flight phases of the expedition (Fig. 1.4). For example, the same

1.4 The International Space Station (ISS) in its current configuration backdropped by Earth. This multinational habitat allows crewmembers to live and work in space for long periods of time. It is an excellent training facility to educate crews for the outbound and return phases of an interplanetary mission, such as an expedition to Mars. NASA digital image dated May 29, 2011

crewmembers could remain on board for the 7–8 month period of time needed to reach Mars, radio contact with Earth could be manipulated to simulate the progressively increasing communication delays that will exist on a trip to the Red Planet, and the crewmembers could practice making their own autonomous decisions separate from those that are made by Mission Control during on-orbit missions. The only thing that can't be simulated is the one-third Earth gravity that will be present on the surface of Mars. However, the one-sixth Earth gravity of the Moon could be used as an approximation of this situation. By actually ferrying the ISS crew to the Moon, the surface exploration of a hostile planetary body could be simulated on the lunar surface. Another stay on the ISS could simulate returning from Mars. So a combined ISS–Moon mission could be used to simulate all of the aspects of a future Mars expedition.

1.5 PUBLIC VERSUS PRIVATE SPACE EXPLORATION

Up until now, we have considered space exploration that is carried out by public organizations: government, military, or a consortium of such groups. True, many publically funded space ventures contract key activities to private companies, such as the building of launch vehicles and the resupply of food and life-support components for the missions. A case in point is United Launch Alliance, which was formed by Lockheed Martin and the Boeing Company at the end of 2006 [21]. It makes the enormously successful Atlas and Delta families of rockets and supplies them under contract to the US government, to NASA, and to other groups to launch payloads into space. Nevertheless, public agencies manage and provide oversight for such activities and, being taxpayer-supported, these agencies do not expect to make money from their activities. However, with the increasing advocacy for space tourism (which we will consider in detail in Chap. 7), more and more private companies are turning to space as a means of generating profits. Some routine space activates, such as the launch of telecommunication and other satellites, are now the purview of the private sector, leaving public agencies to deal with science and exploration. But one must ask the question: is this the best model for the future?

Genta [22] has identified several good reasons to involve private companies in space science and exploration. Many aspects of these missions can be accomplished more cheaply and efficiently by companies that are experienced in space technology and engineering. Also, such companies tend to be less constrained by political and regulatory forces. Since they are able to charge for their services, this puts less demand on public taxpayer money.

One interesting private project is the Mars One initiative, where a Dutch non-profit foundation is planning to establish a permanent human colony on Mars by 2025 [23]. This project will be funded by private grants and donations, by companies interested in paying to have their names associated with the venture, and by advertisement-supported reality TV and Internet broadcasts, which will cover the selection of crewmembers (with public participation) and the crew activities during the trip to Mars and the establishment of the colony on its surface.

Although private involvement in space initially may require government help in the form of grants or prizes, once underway, entrepreneurial activities will take on lives of

their own, assuming that money is made. Space tourism is one potential money-maker. Another source of profits may come from precious metals or minerals that can mined and exported back to Earth. After all, the acquisition of gold, furs, spices, and other valued commodities provided good incentive for semi-private and private companies to explore the New World during the Age of Exploration, and the movement of goods and people has led to a bustling and competitive airline industry. Similar incentives may spur on private space activities in the future.

One drawback discussed by Genta has to do with national legislation and international treaties, which may tend to deal more with public rather than private concerns in space. This situation needs to be changed in order to help private organizations play an active role. Like the airline industry, appropriate regulations need to be in place to assure optimal safety of space travelers and fair competition among space companies, so the public sector will never completely bow out of space activities. But more needs to be done to encourage the private sector's participation, especially for more routine tasks that can benefit the general public.

REFERENCES

1. Rohrer, J. H. (1961). Interpersonal relationships in isolated small groups. In B. E. Flaherty (Ed.), *Symposium on psychophysiological aspects of space flight*. New York: Columbia University Press.
2. Bechtel, R. B., & Berning, A. (1991). The third quarter phenomenon: Do people experience discomfort after stress has passed? In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
3. Kanas, N., & Manzey, D. (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA: Microcosm Press.
4. Kanas, N., & Feddersen, W. E. (1971). *Behavioral, psychiatric, and sociological problems of long-duration space missions. NASA TM X-58067*. Houston, TX: JSC/NASA.
5. Barger, L. K., Flynn-Evans, E. E., Kubey, A., Walsh, L., Ronda, J. M., Wang, W., et al. (2014). Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: An observational study. *Lancet Neurology, 13*, 904–912.
6. Nechaev, A. P. (2001). Work and rest planning as a way of crew member error management. *Acta Astronautica, 49*, 271–278.
7. Barger, L. K., Sullivan, J. P., Vincent, A. S., Fiedler, E. R., McKenna, L. M., Flynn-Evans, E. E., et al. (2012). Learning to live on a mars day: Fatigue countermeasures during the Phoenix Mars Lander Mission. *Sleep, 35*, 1423–1435.
8. Basner, M., Dinges, D. F., Mollicone, D., Ecker, A., Jones, C. W., Hyder, E. C., et al. (2013). Mars 520-d mission simulation reveals protracted crew hypokinesis and alterations of sleep duration and timing. *Proceedings of the National Academy of Sciences, 110*(7), 2635–2640.
9. Welch, R. B., Hoover, M., & Southward, E. F. (2009). Cognitive performance during prismatic displacement as a partial analogue of "space fog". *Aviation, Space, and Environmental Medicine, 80*, 771–780.
10. Strangman, G. E., Sipes, W., & Beven, W. (2014). Human cognitive performance in spaceflight and analogue environments. *Aviation, Space, and Environmental Medicine, 85*, 1033–1048.
11. Mader, T. H., Gibson, C. R., Pass, A. F., Kramer, L. A., Lee, A. G., et al. (2011). Optic disc edema, globe flattening, choroidal folds, and hyperopic shifts observed in astronauts after long-duration spaceflight. *Ophthalmology, 118*, 2058–2069.
12. Marshall-Bowman, K., Barratt, M. R., & Gibson, C. R. (2013). Ophthalmic changes and increased intracranial pressure associated with long duration spaceflight: An emerging understanding. *Acta Astronautica, 87*, 77–87.
13. Eppler, D., & Bleacher, J. (2013). D-RATS mission results. *Acta Astronautica, 90*, 181.

14. Love, S. G., & Bleacher, J. E. (2013). Crew roles and interactions in scientific space exploration. *Acta Astronautica, 90*, 318–331.
15. Litaker, H. L., Jr., & Howard, R. L., Jr. (2013). Social network analysis and dual rover communications. *Acta Astronautica, 90*, 367–377.
16. Kanas, N. (1997). Psychosocial value of space simulation for extended spaceflight. In S. L. Bonting (Ed.), *Advances in space biology and medicine* (Vol. 6). London: JAI Press.
17. Sells, S. B. (1966). A model for the social system for the multiman extended duration space ship. *Aerospace Medicine, 37*, 1130–1135.
18. Suedfeld, P. (1991). Groups in isolation and confinement environments and experiences. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
19. Sandal, G. M., Vaernes, R., Bergan, T., Warncke, M., & Ursin, H. (1996). Psychological reactions during polar expeditions and isolation in hyperbaric chambers. *Aviation, Space, and Environmental Medicine, 67*, 227–234.
20. Bishop, S. L. (2013). From earth analogues to space: Learning how to boldly go. In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin, Germany: Springer.
21. Cress, B. (2014). Chapter 6: Building heavy lift rockets: How United Launch Alliance does it. In K. F. Long (Ed.), *Beyond the boundary: Exploring the science and culture of interstellar spaceflight*. London: Initiative for Interstellar Studies.
22. Genta, G. (2014). Private space exploration: A new way for starting a spacefaring society? *Acta Astronautica, 104*, 480–486.
23. Mars One website. Retrieved from www.mars-one.com

2

Psychological Issues

Some of the psychological stresses that can result from human space missions relate to:

- personality characteristics and selection;
- time effects and third quarter phenomenon;
- initial adjustment and homesickness;
- asthenia;
- habitability issues;
- family concerns;
- post-return issues.

These are normal reactions to the abnormal conditions of space. More severe pathological reactions are discussed in the next chapter.

2.1 PERSONALITY CHARACTERISTICS AND SELECTION

Topping the list are personality characteristics. What traits make a person suitable for flying in space? What makes him or her a good crewmember? Participants in a space crew or planetary colony need to get along with each other, and sometimes personality incompatibilities occur. For example, a loner or a non-team player can disrupt the group's cohesion. What constitutes "the right stuff" to fly into space? What sort of personality mix works, and what doesn't?

The initial screening of applicants to become astronauts is a complex process. In the US space program, this process involves the astronaut selection office, the astronaut corps, aerospace medicine, and space center managers. Personnel in aerospace medicine are responsible for the psychiatric and psychological screening of candidates, which focuses on two different aspects of selection. The first involves the use of psychiatric evaluation and psychological testing to assess for psychopathology, with an emphasis on selecting-out applicants who possess qualities that might represent a risk for behavioral health in space. The second involves psychological evaluation activities aimed at selecting-in the best candidates with respect to specific positive psychological criteria.

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_2

2.1.1 Select-Out: Avoiding Psychopathology

The emphasis of this screening is to select-out people who have serious psychopathology that might become problematic during a mission. Weight is given not only to current mental status and personal history, but also to past and family history. These evaluations usually follow standard medical practices that have been used for decades in aviation and space medicine, and they include both clinical interviews and psychological tests. Since astronaut applicants usually come from a highly selected pool, relatively few candidates are disqualified for psychiatric reasons. For example, in a review of structured clinical interviews on 106 NASA astronaut candidates, only 9 (8.5 %) met criteria for a psychiatric problem, and only 2 (1.9 %) were disqualified on purely psychiatric grounds [1]. Similar procedures used for selecting Japanese astronaut candidates resulted in the disqualification of only 2 out of 45 (4.4 %) applicants [2].

2.1.2 Select-In: "The Right Stuff"

Select-in approaches aim at identifying individuals who can be expected to meet the operational and psychosocial demands of space missions. Assessment tools used for this purpose include interviews, personality and performance tests, analyses of biographical data, and behavioral observations during group activities. Select-in procedures for astronaut candidates have been based more on expert judgment than on systematic research of individual characteristics that best predict success in space [3]. The same goes for crew selection. For example, US crews primarily are assembled from the pool of astronauts based on training and past job performance (such as during previous space missions). Longitudinal studies that identify individual characteristics that produce successful astronauts and lead to good individual performance and team cohesion in space crews should be given priority in future research. One problem has been that personal characteristics that are important for some short-term missions might be completely different from those needed for long-duration missions lasting months or years.

Factors conducive to being a good space crewmember have been thought to include good motivation and judgment, relevant life experiences, cognitive and psychomotor capabilities, cross-cultural competence, personality traits related to coping with stress, and an ability to work alone on a project where appropriate but also evidence of good interpersonal and team-work skills (Fig. 2.1).

2.1.3 Team Cohesion and Compatibility

Putting people together to comprise a compatible team for a space mission typically has depended on factors such as seniority, experience, and ability to work with others during pre-launch training. If an individual does not make the grade physically or psychologically, there is a danger that the entire crew will be grounded in favor of a backup team. Clearly, there needs to be a valid and reliable method of predicting who will get along with whom before training begins, and this has proven to be difficult. Psychometric testing (e.g., the Fundamental Interpersonal Relations Orientation–Behavior (FIRO–B) test; the NEO-PI-R for the "Big Five" personality traits) has shown some promise (see Kanas and Manzey [4] for a review) but more work needs to be done in the space application area.

2.1 Astronaut working on an experiment in the Destiny laboratory of the International Space Station (ISS). People selected for space missions need to be able to work alone diligently on a project for hours on end. NASA/JSC digital image dated March 9, 2012

One method showing promise has been to categorize people in terms of instrumental and expressive traits. Instrumental traits (I) are related to goal-seeking and achievement motivation. Scored in a positive sense (I+), they include high goal-orientation and need for achievement; if negative (I−), this results in arrogance and egotism in striving for work goals. Expressive traits (E) relate to interpersonal relationships. If positive (E+), the individual exhibits kindness and warmth; if negative (E−), verbal aggressiveness and submissive behavior may result [4]. Rating people in this manner has been used successfully in both aviation and space populations, with people scoring high in I+ and E+ being able to work hard for a goal while at the same time relating well with others. Using this system, a group composed of I+/E+ individuals would be expected to be relatively productive and cohesive [5–7].

Another way of comprising a crew is to select people with different but compatible personality characteristics whose needs can be met in a mutually satisfactory manner [8, 9]. For example, two people with a high need for dominance may struggle with each other, whereas one such person may get along fine with a fellow crewmember who does not have such a need. Finding compatible groupings is complicated, and more work needs to be done in this area.

Factors related to the space mission itself also can have an impact on the compatibility and cohesion of space crews. In a survey of 54 astronauts and cosmonauts who had flown in space, Kelly and Kanas [10] looked at issues related to communication that enhanced intra-crew compatibility. Of nine potential factors that were felt to influence crew communication, four were rated as significantly helping: Shared Experience, Excitement of Spaceflight, Close Quarters, and Isolation from Earth. Three others were

judged to hinder communication: Facial Swelling, Spacecraft Ambient Noise, and Space Sickness. These findings suggest that a bonding experience may occur among space travelers who are physically close to one another, who share common experiences, and who are involved with the same activity in a positive, emotionally exciting manner. These investigators also found that fluency in a common language was felt to facilitate interpersonal compatibility.

2.2 TIME EFFECTS AND THIRD QUARTER PHENOMENON

In Sect. 1.1, mention was made of the third quarter phenomenon, where people working under isolated and confined conditions sometimes experience emotional problems after the halfway point of their mission. But how common is this occurrence? Does it affect everyone?

My American and Russian colleagues and I examined this issue in the 1990s and early 2000s in two large international studies involving astronauts and cosmonauts working on the Russian Mir space station and the International Space Station (ISS). The Russian team was headed by V. Salnitskiy. The Mir study sample involved a total of 5 American astronauts, 8 Russian cosmonauts, and 42 American and 16 Russian Mission Control personnel [4, 11–17]. The ISS study sample involved 8 American astronauts, 9 Russian cosmonauts, and 108 American and 20 Russian Mission Control personnel [4, 18–21]. Subjects in these two on-orbit studies completed a weekly research questionnaire that included items from three well-validated and reliable psychological instruments (the Profile of Mood States, or POMS; the Group Environment Scale, or GES; and the Work Environment Scale, or WES), as well as a Critical Incident Log and, in the ISS study, a Culture and Language Questionnaire. In a sense, the ISS study served as a replication of the Mir study, and we found no major differences in the findings between the two. The results were analyzed using appropriate statistical techniques (e.g., mixed-model linear regression, analysis of variance, post-hoc testing) and, due to the large number of analyses performed, adjustments were made to the significance levels to correct for Type I errors (see primary papers for further methodological and statistical details).

One of our hypotheses was that there would be evidence for psychological changes between the first and second halves of the missions, especially in the third quarter. However, we found no significant changes in subscale scores measuring mood, crew cohesion, or interpersonal climate over time, in either the Mir or the ISS studies. In fact, there were no general differences in subscale scores between any of the quarters of the missions. This is not to say that an individual astronaut or cosmonaut did not have a third-quarter dip in mood or morale—a few did. But such drops were countered by other crewmembers who showed mood upswings or no change in emotional status in the third quarter. Taken together, our Mir and ISS subjects were remarkably stable emotionally throughout the missions. These results echo the findings in other studies that found no evidence for a third quarter phenomenon [22–26].

There are several possible explanations for this lack of a third quarter effect, or indeed for any significant time effects in our two studies. First, it may be that our astronauts and cosmonauts were so well trained that they were better able to deal with stress throughout their

missions than a group of less-well-trained polar or submarine workers who show a third-quarter effect. Another explanation is that the excitement of being in space blunted any significant negative feelings our subjects may have experienced. This idea is supported by the finding that ISS crewmember mood was more positive during the missions than before launch, when crews experience the rigors of being in space (e.g., separation from family and friends, tight training schedule) without the exhilaration of the experience [21, 27].

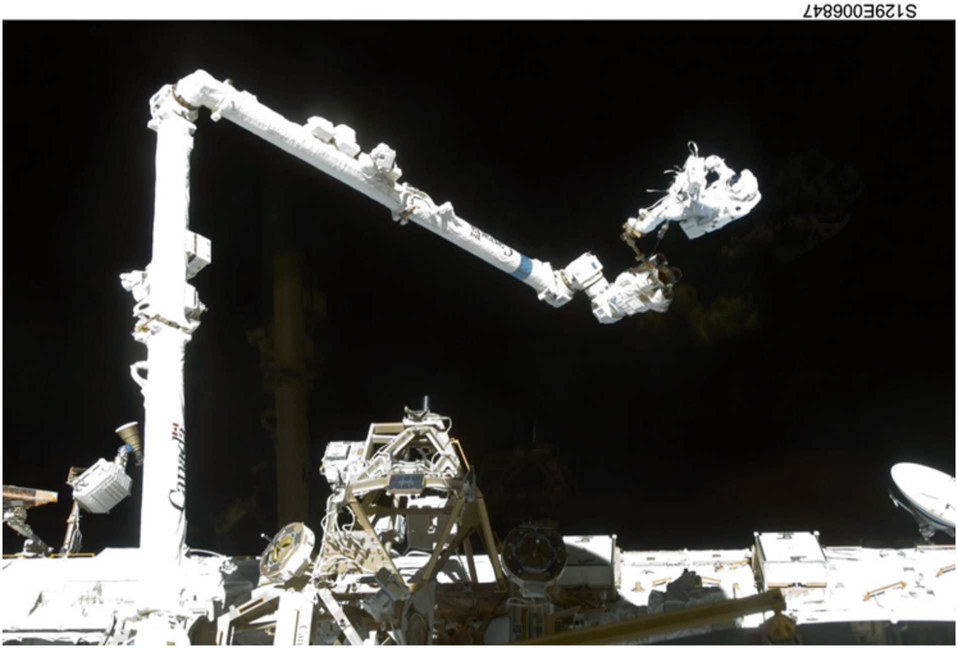
A third possible explanation is that crewmembers participating in on-orbit missions are well supported by space psychologists and flight surgeons in Mission Control who utilize a variety of countermeasures to help them deal with stress and monotony as their mission progresses. For example, it has been observed in such near-Earth missions that, whenever it was felt that a crewmember was becoming despondent, he or she was encouraged to increase communication with family and friends on the ground and was sent up presents and favorite foods during reapply missions to boost morale [4]. Such intensity of support is more difficult to maintain during Antarctic winter-over periods or on submarines during long underwater cruises due to weather or security-related communication problems and to the inability to resupply provisions.

A final explanation may be related to the fact that we used mood and group climate measures that all subjects had to complete, and we examined possible third-quarter effects post study using rigorous statistical methods. In contrast, many other reports of a third-quarter effect have been anecdotal, did not have enough data points to apply statistical methods, or depended on crewmember diary entries that tended to document complaints rather than positive or non-dramatic occurrences (a sort of "squeaky wheel" effect). For example, if one out of three crewmembers mentions a problem in the third quarter, whereas the other two are silent on the matter, then the problem may be scored as being characteristic of space crews. This is compounded where vocal subjects are involved who provide most of the feedback and where no statistical controls are applied to give weight to non-responses.

The lack of a third quarter phenomenon also was reported by Wu and Wang [25] in a study of a group of three people participating in a 105-day isolation mission in the Lunar Palace 1 lunar station simulator in Beijing. Of relevance to our work was the fact that the experimenters used versions of the same instruments we used (Profile of Mood States, Group Environment Scale, and Work Environment Scale) that were adapted for use with Chinese subjects. They tracked their subjects over time and, like us, found no evidence of any change in their measures during the third quarter of the mission. In a manner similar to our studies, they did not find decrements in functions on the GES and WES between the first half and the second halves of the mission. Although this was a study of one small group of people working in a lunar station simulator on Earth, it is striking that their results were so similar to ours in terms of the effects of time on the crewmembers.

2.3 INITIAL ADJUSTMENT AND HOMESICKNESS

Living and working under the conditions of microgravity, isolation, danger, and separation from family and friends are novel experiences (Fig. 2.2). Most people need time to adjust and become oriented to their new environment. But some space travelers experience severe



2.2 Astronaut working on an extravehicular activity (EVA) project anchored at the end of the Canadarm2. Space missions present unique challenges and dangers that astronauts must adjust to during their mission. NASA/JSC digital image dated November 19, 2009

homesickness or even clinical symptoms such as anxiety or depression. For example, one American astronaut sent to the Mir space station reported symptoms of depression and homesickness shortly after arriving due to the isolation he felt on orbit and his separation from his wife [28]. He gradually adjusted to this situation as the mission continued.

In our Mir study, where Americans were seen by their Russian colleagues as "guests" on board their space station, astronauts scored higher than cosmonauts on subscales measuring order and organization, task orientation, and self-discovery during the first few weeks of being on orbit. This suggests the occurrence of a "novelty effect" due to being formally introduced to a new environment that was already known to their Russian counterparts. The scores dropped later in the mission as the Americans became more familiar with their surroundings. This initial American/Russian difference did not occur in our ISS study, probably because the crewmembers from the two countries were seen as equally vital to the mission and had equivalent introductions and exposure to their space habitat.

2.4 ASTHENIA

Russian flight surgeons and space psychologists have identified a type of adjustment reaction called asthenia (sometimes called asthenization), which they believe affects most of their cosmonauts during long-duration space missions. It is defined as a "nervous

or mental weakness manifesting itself in tiredness … and quick loss of strength, low sensation threshold, extremely unstable moods, and sleep disturbance. (Asthenia) may be caused by somatic disease as well as by excessive mental or physical strain, prolonged negative emotional experience or conflict" ([29], p. 28). Russian experts diagnose asthenia by analyzing verbal communications among crewmembers and between crewmembers and personnel in Mission Control; by examining medical information sent to them from space; and by administering clinical scales that assess fatigue, somatic symptoms, sleep quality, and mood. The condition seems to be one of cumulative fatigue that develops over time.

Aleksandrovskiy and Novikov [30] believe that a mild form of asthenia (which they call hyposthenia) appears in many cosmonauts after 1–2 months. They view this state as being characterized by fatigue, decreased work capacity, sleep problems, anxiety, autonomic disturbances (e.g., heart palpitations, perspiration), attention and concentration difficulties, and heightened sensitivity to bright lights and loud noises.

Such perceptual changes have been reported empirically by space travelers. In a questionnaire study of 54 astronauts and cosmonauts who had flown in space, the subjects stated that watching and listening activities significantly increased during both work and leisure time periods [10]. This was reminiscent of reports that, during Salyut 6 and 7, heightened perceptual sensitivities were noted after 3–5 months, with some cosmonauts stating that they became increasingly disturbed by loud sounds and the manner of verbal presentations from people in Mission Control [31, 32].

Asthenia is seen as a variant of neurasthenia, a neurotic mental disorder that was first described by the American physician George Beard (1839–1883). He viewed it as resulting from the dramatic social changes that were occurring in the US during the nineteenth Century, which particularly affected the upper classes [33, 34]. Myasnikov et al. [35] have contrasted the clinical condition on Earth with asthenia in space. They believe that the latter condition is milder because cosmonauts are carefully screened for psychiatric problems and because simple countermeasures employed early, such as increased stimulation and contact with loved ones on Earth, help to ameliorate the condition and avoid the need for medications and psychotherapy.

Symptoms and signs suggestive of asthenia have been reported by American astronauts who have flown in space during long-duration space missions [36–38]. However, as part of a general trend over the past couple of decades toward redefining neurotic diagnoses in the US, neither asthenia nor neurasthenia is given official diagnostic status by the American Psychiatric Association, although these conditions still are recognized in Russia, Europe, China, and elsewhere in the world. For American mental health workers, the corresponding symptoms are included in such entities as adjustment, dysthymic, or major depressive disorders, or chronic fatigue syndrome. In Sect. 5.3, we will examine further some cultural differences regarding asthenia in space.

We conducted a retrospective analysis of the Profile of Mood States data from our Mir study to look for changes suggestive of asthenia [34]. Three of the study investigators independently identified eight items on the POMS as being characteristic of early asthenia. Six Russian space experts, who were familiar with the symptoms and signs of asthenia and who had worked directly with cosmonauts for 10 years or more, provided minimum scores on these items that they felt would be indicative of clinical asthenia. When compared with

these prototype values, our subjects scored significantly lower on all eight items, which suggested an absence of asthenia among our subjects. However, it should be noted that the POMS could only evaluate the emotional and not the physiological aspects of asthenia, and it might be that these eight items were not sensitive enough to retrospectively identify characteristics of the syndrome. Despite the negative findings, the concept of asthenia warrants further study using a prospective methodology and measures more specific and sensitive to the symptoms and signs of asthenia.

2.5 HABITABILITY ISSUES

Habitability refers to the physical interface between the environment and the human being. When the living quarters are pleasantly constructed, the on-board equipment and displays are user-friendly, and the lighting and noise are optimal for human use, then this can improve the well-being of the inhabitants. The opposite situation can occur as well, so the nature of the environment plays a big role in human psychology and performance. Ergonomics experts and human factors engineers are usually tasked with the responsibility of making the environment pleasant and user-friendly. This is not always easy, since other engineering demands may impede the optimization of the right environment. For example, structural needs may restrict the amount of space available for windows, or space limitations may influence the design and operation of a proper toilet. Over the years, a number of designs have been used that have reflected the needs and goals of space missions [39].

In general, a space habitat should include some ability to visualize the outside, provisions for privacy, a pleasant color scheme and placement of equipment, buffering of excessive noise and vibration to enhance sleep and peace of mind, and enough flexibility to allow crewmembers to personalize it to their needs. Enough work stations should be available to perform required activities, and space needs to be dedicated for leisure time and recreational pursuits. In manned missions, humans should be seen as an important part of the total system, and their needs should be given top priority.

2.6 FAMILY CONCERNS

Flying on a space mission is an exciting event. However, it also can be demanding, not only for the space traveler, but for his or her family as well. Johnson et al. [40] conducted interviews with 20 retired male cosmonauts and used a thematic scoring scheme to code for work–family interactions. They found that the majority of these interactions indicated that work overflowed into family life and hindered or interfered with family functioning (e.g., less time spent with the family, inhibition of the spouse's career plans, frequent family relocations). The most common resolution was that the family adjusted to the cosmonaut's work demands rather than the opposite, except when a significant need arose, such as a family illness or the birth of a child. Not all respondents saw this work accommodation as negative; some viewed it positively or accepted it as part of the job. The investigators reported that the Russian Federal Space Agency attempted to respond to cosmonaut

requests for more family time by such actions as arranging communication sessions during a mission and adjusting the work schedule to accommodate such sessions.

Johnson [41] also qualitatively analyzed a number of oral histories, pre-flight interviews, and journal entries of astronauts participating in Skylab, Mir, and ISS missions to assess their views of the roles of NASA, the astronauts themselves, and their families in helping to create a daily life that mirrored psychosocial aspects of life on Earth. She concluded that NASA's role is to schedule worthwhile activities in space and to facilitate communication between the astronauts and the ground; the astronaut's role is to personalize leisure time, connect looking out the window with specific aspects of life on Earth, make daily on-orbit routine activities fun, and celebrate traditions and historical space events; and the family's role is to participate in two-way communication with the astronauts and to send them personalized care packages with treats and reminders of home via resupply ships.

Contact with family members and friends on Earth is very important for crewmembers during their missions. In their questionnaire survey of astronauts and cosmonauts, Kelly and Kanas [42] found that respondents rated the value of contact with loved ones on Earth as having a significantly positive influence on their performance. Long-duration space travelers rated this item higher than those spending fewer than 20 days in space. Several subjects mentioned the need to have private space–ground audiovisual links available for crewmembers to talk with their family and friends. Similar results from Antarctica were reported by Palinkas and his colleagues [43], who found that support provided by contact with family and friends back home was more important for stabilizing mood and performance than support that was given by fellow crewmates (Fig. 2.3).

2.3 An important support tool for International Space Station (ISS) astronauts is the Softphone (as in "software"). This works through on-board laptop computers via Internet Protocol (IP) information packets, whereby communications with family and friends on Earth are routed by way of satellites. Astronauts and their loved ones can communicate privately pretty much at any time. NASA image, NASAexplores, March 6, 2003

One important issue related to the contact between families on Earth and crewmembers in space is how to inform an astronaut or cosmonaut of bad news from home. During a Salyut 6 mission, authorities delayed telling one cosmonaut about the death of his father until he returned to Earth, fearing that the bad news would negatively affect his performance [44]. In their survey, Kelly and Kanas [42] reported that 18 respondents were of the opinion that negative personal information (such as a death in the family) should be withheld until a space traveler completes the mission, whereas another 22 stated that it should not be withheld. Five additional respondents gave no clear opinion. It was concluded that a reasonable compromise before long-duration missions is for mission support personnel to discuss this issue with each astronaut or cosmonaut before launch in order to assess his or her personal preferences regarding disclosure, and this is the policy today. When disclosed, bad news from home should be tempered with support and should probably be delayed until after the completion of a critical mission activity. Support mechanisms also need to be available, such as on-board counseling, brief psychotherapy, and sedative medication.

Many astronauts have commented that a major issue for them is the status and well-being of their family back home. Family members on Earth should be supported while their loved ones are in space. This can include family briefings, support during launch and landing, family conferences, peer-led support groups, and even individual counseling sessions that are sponsored by the space agencies. Psychotherapy and medications also need to be available when indicated. Such support will not only benefit families, but it can help to maintain the crewmembers' concentration on the mission tasks by relieving them of excessive worry about problems at home and feelings of abandoning their families during a crisis.

2.7 POST-RETURN ISSUES

Some astronauts have reported having transcendent or religious experiences while in space or being humbled by thoughts related to the beauty of Earth or their relative insignificance in the vastness of the cosmos [45]. As a result, they have exhibited personality changes or increased sensitivity to human needs after returning home. Other space travelers have had more negative experiences related to readjustment, particularly to the lack of privacy and to the fame and glory that a highly visible mission engenders. These readjustment complications can be serious and include such experiences as clinical depression, substance abuse, and marital difficulties. These sorts of problems affected Apollo astronaut Buzz Aldrin after he came back from the Moon [46]. Post-seclusion anxiety and suspiciousness also were noted in a crewmember who had participated in a 90-day closed-chamber space simulation study [47].

Problems also have affected the family dynamics of individuals returning home after long periods of separation. Isay [48] studied 432 wives living on a submarine base and found that most of them had adjusted to the absence of their husbands. However, nearly two-thirds experienced depression when their spouse returned from sea patrol and tried to reassert his role in the family constellation, thereby disrupting the equilibrium that had been established. Isay called this "the submariners' wives syndrome". Pearlman [49]

2.4 Apollo crewmembers greeted by spouses and children shortly after returning. It is important for families to have some private time together as soon as possible to give them time to readjust with one another. NASA/JSC digital image dated November 19, 1969

likewise found that serious marital problems occurred in families following the return of the husbands from submarine patrol. Similar family difficulties have been reported following Antarctic expeditions [50, 51]. Thus, long-duration separations can take their toll on families, even after the members are reunited.

Supportive activities for space travelers and their families need to continue into the post-mission period [52]. It is important that astronauts and their families be reunited as soon as possible after a mission and that they be given a period of time to reconnect (Fig. 2.4). Long separations can be stressful for a family. This is especially true after a highly publicized mission that involves extensive post-return press coverage. Many astronauts and their families are not used to the stress that can be caused by a media barrage, and they will need a period of enforced privacy to facilitate the family reunion process. Supportive debriefings and formal counseling resources also should be available for families that need additional help in the readjustment process.

REFERENCES

1. Santy, P., Endicott, J., Jones, D. R., Rose, R. M., Patterson, J., Holland, A. W., et al. (1993). Results of a structured psychiatric interview to evaluate NASA astronaut candidates. *Military Medicine, 158*, 5–9.
2. Endo, T., Ohbayashi, S., Yumikura, S., & Sekiguchi, C. (1994). Astronaut psychiatric selection procedures: A Japanese experience. *Aviation, Space, and Environmental Medicine, 65*, 916–919.
3. Santy, P. A. (1994). *Choosing the right stuff: The psychological selection of astronauts and cosmonauts*. Westport, CT: Praeger Scientific.

4. Kanas, N., & Manzey, D. (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA: Microcosm Press.
5. Chidester, T. R., Helmreich, R. L., Gregorich, E., & Geis, C. E. (1991). Pilot personality and crew coordination: Implications for training and selection. *International Journal of Aviation Psychology, 1*, 25–44.
6. McFadden, T. J., Helmreich, R. L., Rose, R. M., & Fogg, L. F. (1994). Predicting astronaut effectiveness: A multivariate approach. *Aviation, Space, and Environmental Medicine, 65*, 904–909.
7. Sandal, G., Vaernes, R., Bergan, T., Warncke, M., & Ursin, H. (1996). Psychological reactions during polar expeditions and isolation in hyperbaric chambers. *Aviation, Space, and Environmental Medicine, 67*, 227–234.
8. Haythorn, W. W. (1970). Interpersonal stress in isolated groups. In M. J. McGrath (Ed.), *Social and psychological factors in stress*. New York: Holt, Rinehart & Winston.
9. Haythorn, W. W., McGrath, J. E., Hollander, E. P., Latané, B., Helmreich, R., & Radloff, R. (1972). Group processes and interpersonal interaction. In Space Science Board (Ed.), *Human factors in long-duration spaceflight*. Washington, DC: National Academy of Sciences.
10. Kelly, A. D., & Kanas, N. (1992). Crewmember communication in space: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 63*, 721–726.
11. Kanas, N., Salnitskiy, V., Grund, E. M., Gushin, V., Weiss, D. S., Kozerenko, O., et al. (2000). Social and cultural issues during Shuttle/Mir space missions. *Acta Astronautica, 47*, 647–655.
12. Kanas, N., Salnitskiy, V., Grund, E. M., Gushin, V., Weiss, D. S., Kozerenko, O., et al. (2000). Interpersonal and cultural issues involving crews and ground personnel during Shuttle/Mir space missions. *Aviation, Space, and Environmental Medicine, 71*(9, Suppl.), A11–A16.
13. Kanas, N., Salnitskiy, V., Weiss, D. S., Grund, E. M., Gushin, V., Kozerenko, O., et al. (2001). Crewmember and ground personnel interactions over time during Shuttle/Mir space mission. *Aviation, Space, and Environmental Medicine, 72*, 453–461.
14. Kanas, N., Salnitskiy, V., Grund, E. M., Weiss, D. S., Gushin, V., Kozerenko, O., et al. (2001). Human interactions during Shuttle/Mir space missions. *Acta Astronautica, 48*, 777–784.
15. Kanas, N., Salnitskiy, V., Grund, E. M., Weiss, D. S., Gushin, V., Kozerenko, O., et al. (2001). Human interactions in space: Results from Shuttle/Mir. *Acta Astronautica, 49*, 243–260.
16. Kanas, N., Salnitskiy, V., Grund, E. M., Weiss, D. S., Gushin, V., Bostrom, A., et al. (2001). Psychosocial issues in space: Results from Shuttle/Mir. *Gravitational and Space Biology Bulletin, 14*(2), 35–45.
17. Kanas, N., Salnitskiy, V., Grund, E. M., Gushin, V., Weiss, D. S., Kozerenko, O., et al. (2002). Lessons learned from Shuttle/Mir: Psychosocial countermeasures. *Aviation, Space, and Environmental Medicine, 73*, 607–611.
18. Kanas, N. A., Salnitskiy, V. P., Ritsher, J. B., Gushin, V. I., Weiss, D. S., Saylor, S. A., et al. (2006). Human interactions in space: ISS vs. Shuttle/Mir. *Acta Astronautica, 59*, 413–419.
19. Kanas, N. A., Salnitskiy, V. P., Ritsher, J. B., Gushin, V. I., Weiss, D. S., Saylor, S. A., et al. (2007). Psychosocial interactions during ISS missions. *Acta Astronautica, 60*, 329–335.
20. Kanas, N. A., Salnitskiy, V. P., Ritsher, J. B., Gushin, V. I., Weiss, D. S., Saylor, S. A., et al. (2007). Crewmember and mission control personnel interactions during International Space Station missions. *Aviation, Space, and Environmental Medicine, 78*, 601–607.
21. Boyd, J. E., Kanas, N. A., Salnitskiy, V. P., Gushin, V. I., Saylor, S. A., Weiss, D. S., et al. (2009). Cultural differences in crewmembers and mission control personnel during two space station programs. *Aviation, Space, and Environmental Medicine, 80*, 532–540.
22. Kanas, N., Weiss, D. S., & Marmar, C. R. (1996). Crewmember interactions during a Mir space station simulation. *Aviation, Space, and Environmental Medicine, 67*, 969–975.
23. Steel, G. D., & Suedfeld, P. (1991). Temporal patterns of affect in an isolated group. *Environment and Behavior, 23*, 749–765.
24. Wood, J.-A., Lugg, D. J., Hysong, S. J., & Harm, D. L. (1999). Psychological changes in hundred-day remote Antarctic field groups. *Environment and Behavior, 31*, 299–337.

25. Wu, R., & Wang, Y. (2014). Psychosocial interaction during a 105-day isolated mission in LUNAR PALACE 1. In: *IAC-14-A1.1.2, 65th International Astronautical Congress, Toronto, ON, Canada.*
26. Basner, M., Dinges, D. F., Mollicone, D. J., Savelev, I., Ecker, A. J., Di Antonio, A., et al. (2014). Psychological and behavioral changes during confinement in a 520-day simulated interplanetary mission to Mars. *PLoS One, 9*(3), e93298. doi:10.1371/journal.pone. 0093298.
27. Ritsher, J. B. (2005). Cultural factors and the International Space Station. *Aviation, Space, and Environmental Medicine, 76*(6 Suppl), B135–B144.
28. Astronaut tells of down side to space life. *New York Times*. Retrieved January 22, 1997, from www.nytimes.com/1997/01/22/us/astronaut-tells-of-down-side-to-space-life.html?ref=johneblaha
29. Petrovsky, A. V., & Yaroshevsky, M. G. (1987). *A concise psychological dictionary*. Moscow, Russia: Progress.
30. Aleksandrovskiy, Y. A., & Novikov, M. A. (1996). Psychological prophylaxis and treatments for space crews. In A. E. Nicogossian, S. R. Mohler, O. G. Gazenko, & A. I. Grigoriev (Eds.), *Space biology and medicine III: Humans in spaceflight, book 2*. Reston, VA: AIAA.
31. Grigoriev, A. I., Kozerenko, O. P., Myasnikov, V. I., & Egorov, A. D. (1988). Ethical problems of interaction between ground-based personnel and orbital station crewmembers. *Acta Astronautica, 17*, 213–215.
32. Lebedev, V. (1988). *Diary of a cosmonaut: 211 days in space*. College Station, TX: Phytoresource Research Information Service.
33. Beard, G. M. (1971). *A practical treatise on nervous exhaustion (neurasthenia), its symptoms, nature, sequences, treatment* (5th ed.). New York: E.B. Treat. Reprinted from 1971 Kraus Reprint, New York: Kraus-Thomson Organization Limited.
34. Kanas, N., Salnitskiy, V., Gushin, V., Weiss, D. S., Grund, E. M., Flynn, C., et al. (2001). Asthenia: Does it exist in space? *Psychosomatic Medicine, 63*, 874–880.
35. Myasnikov, V. I., Stepanova, S. I., Salnitskiy, V. P., Kozerenko, O. P., & Nechaev, A. P. (2000). *Problems of psychic asthenia in prolonged space flight*. Moscow, Russia: Slovo Press (in Russian).
36. Burrough, B. (1998). *Dragonfly: NASA and the crisis aboard Mir*. New York: Harper Collins.
37. Freeman, M. (2000). *Challenges of human space exploration*. Chichester, England: Springer.
38. Harris, P. R. (1996). *Living and working in space: Human behavior, culture and organization* (2nd ed.). Chichester, England: Wiley.
39. Kitmacher, G. H. (2002, Oct 10–19). Design of the space station habitable modules. In: *IAC-02-IAA.8.2.04, 53rd International Astronautical Congress/The World Space Congress, Houston, TX* (pp. 1–17). Retrieved from www.spacearchitect.org/pubs/IAC-02-IAA.8.2.04.pdf
40. Johnson, P. J., Asmaro, D., Suedfeld, P., & Gushin, V. (2012). Thematic content analysis of work–family interactions: Retired cosmonauts' reflections. *Acta Astronautica, 81*, 306–317.
41. Johnson, P. J. (2013). The roles of NASA, U.S. Astronauts, and their families in long-duration missions. In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin, Germany: Springer.
42. Kelly, A. D., & Kanas, N. (1993). Communication between space crews and ground personnel: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 64*, 795–800.
43. Palinkas, L. A., Gunderson, E. K. E., Holland, A. W., Miller, C., & Johnson, J. C. (2000). Predictors of behavior and performance in extreme environments: The Antarctic space analogue program. *Aviation, Space, and Environmental Medicine, 71*, 619–625.
44. Oberg, J. E. (1981). *Red star in orbit*. New York: Random House.
45. Kanas, N. (1990). Psychological, psychiatric, and interpersonal aspects of long-duration space missions. *Journal of Spacecraft and Rockets, 27*, 457–463.
46. Aldrin, E. E. (1973). *Return to earth*. New York: Random House.
47. Seeman, J. S., & MacFarlane, T. G. (1972). *Results of post-test psychological examinations of the crewmen from the 90-Day manned test of an advanced regenerative life support system. NASA CR-112019*. Huntington Beach, CA: McDonnell Douglas Corporation.
48. Isay, R. A. (1968). The submariners' wives syndrome. *Psychiatric Quarterly, 42*, 647–652.
49. Pearlman, C. A., Jr. (1970). Separation reactions of married women. *American Journal of Psychiatry, 126*, 946–950.

50. Oliver, D. C. (1991). Psychological effects of isolation and confinement of winter-over group at McMurdo station, Antarctica. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
51. Taylor, A. J. W. (1991). The research program of the International Biomedical Expedition to the Antarctic (IBEA) and its implications for research in outer space. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
52. Sipes, W., & Vander Ark, S. (2005). Operational behavioral health and performance resources for International Space Station crews and families. *Aviation, Space, and Environmental Medicine, 76*, B36–B41.

3

Psychiatric Issues

Some of the psychiatric stresses that have been associated with human space missions relate to:

- adjustment disorders;
- somatoform disorders;
- clinical depression;
- psychotic reactions;
- suicidal/homicidal ideation or intent;
- substance abuse.

Such problems may be pathological reactions to the abnormal conditions of space, or they may represent reactions that coincidentally occurred due to genetic or constitutional predispositions whose time had come. Because astronauts are screened for personal or family histories of these disorders, the likelihood of their developing in space travelers is lower than in the general population. But, since some of these conditions may occur later in life after someone has been selected to be an astronaut (e.g., bipolar disorder), they still may occur despite the screening. In addition, everyone has their breaking point when exposed to severe stressors, so no one is completely immune to having psychotic or suicidal/homicidal reactions in space.

3.1 PSYCHIATRIC PROBLEMS IN SPACE

3.1.1 Adjustment Disorders

As discussed in the last chapter, difficulty in adjusting to the novelties of space is a common occurrence. Sometimes, this can affect morale and produce transient homesickness or depression. Simple procedures such as increasing contact with family and friends on Earth or sending up presents via resupply spacecraft can counter this dysphoria (Fig. 3.1). But, at other times, this adjustment may take on pathological proportions and become a diagnosable disorder. Severe anxiety, depression, and other symptoms of mental illness may occur that require medications and psychotherapy. For example, cosmonaut Lebedev [1] cited several problems he had in adjusting to the monotonous conditions that occurred

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_3

3.1 ISS crewmembers showing off crew care packages containing items specially selected for them that were brought by a resupply ship. Receipt of such items boosts morale and helps counter adjustment problems in space. ESA/NASA image dated January 31, 2011

during his Salyut 7 mission. These included despondency, withdrawal, and tense relations with his crewmate. In such cases, a brief course of tranquilizers or counseling can help resolve the adjustment issues. In some isolated and confined environments on Earth, such as in submarines or Antarctic bases, symptoms have progressed to psychotic reactions and suicidal ideation, as will be discussed below.

Adjustment problems also may result from tensions due to differences in crewmember personality, background, and attitudes. Space travelers highly value commonalities that they have with their fellow crewmates. In a questionnaire survey of 54 astronauts and cosmonauts who had flown in space, Kelly and Kanas [2] found that a sense of sharing common experiences and mutual excitement over the mission were two factors that were rated as significantly enhancing crewmember communication in space.

3.1.2 Somatiform Disorders

Some space travelers somaticize their psychiatric problems and experience them in terms of bodily symptoms, such as stomach upset, headaches, or even toothaches. For example, one Salyut 6 cosmonaut wrote in his diary about his fear of having an appendicitis attack during the mission. He also reported having pain in his tooth after awakening from a dream of a toothache [3]. A Salyut 7 cosmonaut was brought back early from his mission for poor work performance that was due to fatigue, listlessness, and psychosomatic concerns related to perceived prostatitis and fears of impotence [4]. Another cosmonaut

experienced tension, fatigue, and cardiac arrhythmias following a series of misfortunes and accidents involving the Mir space station. As a result, his work duties were altered, and he was prescribed sedatives [5].

Psychosomatic symptoms also have occurred during space analog missions. For example, Lugg [6] included psychalgia (tension headaches) as one of the most common mental problems reported during Australian Antarctic expeditions over a 25-year period. Weybrew [7] found that, on an average day, a quarter of the men on submarine missions experienced headaches. Although environmental factors such as toxins in the atmosphere may have played a role in producing problems such as headaches, they could not alone account for the high incidence of concerns over physical issues that were reported by the crew.

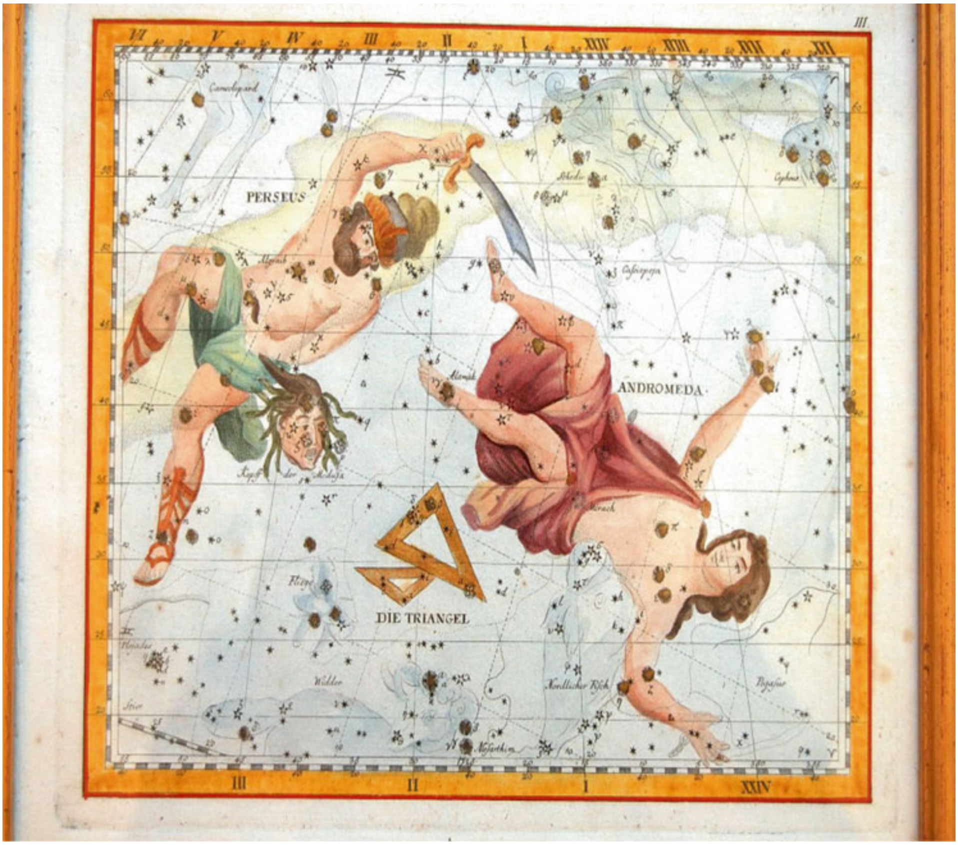
3.1.3 Serious Mental Disorders

Feeling blue, homesick, and even depressed at times is not unusual for people living and working in isolated and confined environments (ICEs) away from home. However, the full diagnostic spectrum of clinical depression (e.g., long periods of depressed mood, low energy, sleep and appetite problems, suicidal intent or plan) that requires psychotherapeutic and psychopharmacologic intervention is not common during space missions. Similarly, psychotic conditions such as bipolar (e.g., manic–depressive) disorder and schizophrenia have not been reported during space missions. This in part is due to the fact that these conditions are associated with genetic and constitutional predispositions, and they occur relatively early in adult life, before the usual age of astronaut selection. An exception is bipolar disorder, which can first become manifest as late as in the thirties in predisposed individuals. Since astronaut candidates are carefully screened psychiatrically to rule out such problems before they enter the corps, one would not expect to find many people vulnerable for these conditions in the astronaut pool (Fig. 3.2). However, anyone can experience a transient psychotic reaction if placed under enough stress, so psychosis during a space mission can’t be ruled out.

Other psychiatric problems that can produce mood alterations or psychotic thinking, such as alcohol or drug abuse or withdrawal, are not present in space due to the unavailability of the offending substance. However, as will be considered in Chap. 7, consideration is being given to providing alcohol to space tourists, much as occurs during long-distance airplane trips on Earth. In addition, in space colonies where people live and work for much of their lives, the presence of alcohol is likely to be an occurrence. So, as a mechanism for dealing with the stressors of space-related ICEs, substance usage may become more common, and substance abuse cannot be ruled out as a likely occurrence in some members of the population.

3.1.4 Frequency of Psychiatric Problems

Psychiatric problems affecting space travelers are relatively rare as compared with the general population, and those that have occurred have been relatively mild. Shepanek [8] reported 34 negative behavioral signs and symptoms that took place in the 1980s during Space Shuttle missions, and only two psychiatric events that affected the seven American astronauts who flew on the Mir space station from 1995 to 1998. These difficulties included anxiety and depression, memory and problem-solving impairments, withdrawal, and



3.2 Greek mythology envisioned the heavens as being populated with heroic people, gods, and goddesses, such as a victorious Perseus holding Medusa's head next to a welcoming Andromeda. But real astronauts may feel insignificant venturing into deep space, being isolated from family and friends back home. This can result in homesickness, psychological problems, and interpersonal conflicts. This image is from the 1782 edition of Johann Bode's star atlas *Vorstellung der Gestirne auf XXXIV Kupfertafeln ….* The image is courtesy of the Nick and Carolynn Kanas Collection; and *Star Maps: History, Artistry, and Cartography, 2nd ed.*, Nick Kanas, Springer/Praxis, 2012

interpersonal conflicts. In some cases, productivity was affected. Santy [9] reported that the incidence of psychiatric disorders in a study of 223 astronaut applicants was 9 %. Of these 20 affected individuals, five had family problems, four had a personality disorder, three had a life circumstance problem, and two each suffered from bereavement, anxiety disorder, adjustment disorder, or major depression. None of these people had schizophrenia.

But severe emotional problems have occurred in the less carefully screened populations participating in space analog settings. Gunderson [10] reported that 3 % of naval personnel stationed in the Antarctic experienced psychiatric problems versus 1 % of similar personnel based in other duty locations. In his review of the Australian Antarctic

experience, Lugg [6] concluded that mental disorders accounted for 4–5 % of the total morbidity, although severe psychotic and neurotic illnesses were much lower than 4 %. Palinkas and his colleagues [11, 12] reported on 313 military and civilian personnel who spent an austral winter at South Pole Station and McMurdo Station. They found that 5.2 % of the subjects had symptoms of a psychiatric problem. Mood and adjustment disorders comprised 31.6 % of these difficulties, followed by sleep-related problems (21 %), drug-related disorders (10.5 %), and personality disorders (7.9 %). Interestingly, these problems developed despite the fact that all subjects had passed a psychiatric and psychological screening procedure prior to their assignment for remote duty in the Antarctic.

Psychiatric difficulties also have occurred during submarine missions. Serxner [13] reported a 5 % incidence of psychiatric problems (including psychosis) in his report of two cruises of the Polaris submarine. In a review of 30 years of research involving nuclear submarines, Weybrew [7] concluded that the incidence of acute and chronic psychopathology during the longer missions was 1–4 %. Anxiety and depressive reactions were most frequent, followed by personality disorders and psychophysiological reactions. In a review of nuclear submarine missions [14], 1.2 % of the men suffered from severe psychiatric problems: 50 % were related to severe anxiety, 39 % to interpersonal difficulties, and 29 % to depression.

3.2 TREATMENT CONSIDERATIONS

3.2.1 Psychoactive Medications

A variety of psychoactive medications have been available to crewmembers during space missions. For example, medications on Space Shuttle flights have included: anti-anxiety medications, such as diazepam; antipsychotic medications, such as haloperidol; pain medications, such as codeine and morphine; medications for sleep, such as flurazepam and temazepam; stimulants, such as dextroamphetamine; and promethazine for space motion sickness (Fig. 3.3) [15]. Some 78 % of Space Shuttle crewmembers have taken medications in space, primarily for space motion sickness (30 %), headache (20 %), insomnia (15 %), and back pain (10 %) [16]. Newer psychoactive medications also were included on some flights, such as the so-called "atypical" antipsychotics (e.g., olanzapine, risperidone) and the selective serotonin reuptake inhibitor (SSRI) antidepressants (e.g., fluoxetine, sertraline). Such medications also have been used on Russian space missions and have included anti-anxiety agents, such as diazepam and phenazepam; antidepressants, such as amitriptyline; antipsychotics, such as chlorpromazine and haloperidol; and stimulants [17].

Physiological changes resulting from microgravity that can alter the pharmacokinetic characteristics of psychoactive drugs include:

- blood and fluid shifts from the lower to the upper body;
- decreased gastric emptying;
- reduced intestinal absorption;
- decreased first pass effect in the liver;
- alterations in protein binding in the blood;
- changes in renal excretion rates.

3.3 Space Shuttle crewmembers inspect the contents of their emergency medical and medication kits during a pre-launch review. Most astronauts take medications during a mission, especially for space motion sickness and headaches. NASA/JSC digital image dated January 31, 1989

Many of these effects can influence medication dosage and route of administration. For example, decreased gastric emptying and lowered intestinal absorption can act to decrease the effect of medications that are administered by mouth. Psychoactive medications that are variably absorbed by the gut, such as chlorpromazine, flurazepam, and morphine, may especially be vulnerable to these changes. Fluid shifts may lower the blood-borne bioavailability of medications to the liver (the first pass effect), where they normally would be metabolized. Especially sensitive to this influence are morphine and many antidepressants [18]. Surprisingly, little empirical work has been done on the pharmacokinetics of medications under conditions of microgravity, and more pharmacological experiments in space need to be done.

In considering future long-duration space missions, Santy [19] has written that a reasonable psychiatric formulary should consist of examples from each of the major psychoactive drug classes: anti-anxiety agents, antidepressants, antipsychotics, sedatives and hypnotics, and medications to counter mania and other mood swings. The use of these medications should be monitored carefully, since a number of them have a potential for abuse and since novel effects may emerge in the space environment. On one Russian space mission, for example, the commander suffered from insomnia and took too many sleeping pills without informing physicians in Mission Control. He subsequently developed a number of problems attributable to this action [17]. Thus, supervision of psychoactive drug usage in space by experts on the ground or medically trained crewmembers in space is important.

3.2.2 Counseling and Psychotherapy

During near-Earth missions, counseling sessions, crisis intervention, or brief supportive psychotherapy can occur between individuals in the crew and therapists on the ground using private two-way audiovisual links. On rare occasions, insight-oriented psychotherapy may be indicated. Crewmembers can be monitored from the ground for symptoms and signs of developing psychiatric disturbances in real time.

During deeper space missions (such as a trip to Mars), the distance between the crew and Earth results in communication delays. This impedes the ability to monitor and to conduct counseling and psychotherapy sessions in real time from Mission Control. It also impedes supportive family–crewmember interactions and limits the ability to send morale-enhancing supplies and gifts up from Earth. As a result, the identifications of psychiatric problems and their psychoactive and therapeutic treatment will depend upon the skills of on-board crewmembers who are trained in counseling, psychotherapy, and the use of medications. Facilities also need to be available on board to seclude and restrain a potentially suicidal or violent crewmember.

It is unlikely that a psychiatrist will be a member of the crew in early missions involving a lunar base or a trip to a distant planet. However, it is likely that a physician or some other medically trained individual will be present on board. In addition to medical and surgical skills, such a physician should possess a knowledge of: (i) individual psychopathology and small group behavior; (ii) the individual and interpersonal effects of stressors to be expected during the mission; (iii) techniques involving crisis intervention, individual psychotherapy, and the facilitation of group awareness and team-building; and (iv) the appropriate use of tranquilizers and other psychoactive medications, including their usefulness and side effects under conditions of microgravity [20]. To protect the crew in the event that the physician develops a psychiatric (or medical) problem, at least one other person needs to be trained to deal with such issues. In addition, all of the crewmembers should be sensitized to important psychiatric and interpersonal problems that might occur during the course of long-duration space missions, as well as to basic interventions for dealing with such difficulties.

REFERENCES

1. Lebedev, V. (1988). *Diary of a cosmonaut: 211 days in space*. College Station, TX: Phytoresource Research Information Service.
2. Kelly, A. D., & Kanas, N. (1992). Crewmember communication in space: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 63*, 721–726.
3. Chaikin, A. (1985). The loneliness of the long-distance astronaut. *Discover 1985, 6*, 20–31.
4. Harris, P. R. (1996). *Living and working in space: Human behavior, culture and organization* (2nd ed.). Chichester, England: Wiley.
5. Carpenter, D. (1997). Are blunders on Mir signs the stress is too great? *San Francisco Examiner*, July 18, 1997, p. A–1.
6. Lugg, D. J. (1991). Current international human factors research in Antarctica. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
7. Weybrew, B. B. (1991). Three decades of nuclear submarine research: Implications for space and Antarctic research. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
8. Shepanek, M. (2005). Human behavioral research in space: Quandaries for research subjects and researchers. *Aviation, Space, and Environmental Medicine, 76*(6, Suppl.), B25–B30.

9. Santy, P. A. (1997). Behavior and performance in the space environment. In S. E. Church (Ed.), *Fundamentals of space life sciences* (Vol. 2). Malabar, FL: Krieger Publishing Company.
10. Gunderson, E. K. E. (1968). Mental health problems in Antarctica. *Archives of Environmental Health, 17*, 558–564.
11. Palinkas, L. A. (2001). Psychosocial issues in long-term spaceflight: Overview. *Gravitational and Space Biology Bulletin, 14*, 25–33.
12. Palinkas, L. A., Glogower, F., Dembert, M., Hansen, K., & Smullen, R. (2001, January 16). Psychiatric morbidity after extended isolation and confinement in an extreme environment: The Antarctic-space analog program. *Proceedings of the 2nd Biennial Conference on Bioastronautics, Galveston, TX*.
13. Serxner, J. L. (1968). An experience in submarine psychiatry. *American Journal of Psychiatry, 125*, 25–30.
14. Boeing Aerospace Company. (1983). *Space station/nuclear submarine analogs. CCO271*. Grenada Hills, CA: National Behavior Systems.
15. Pavy-Le Traon, A., Saivin, S., Soulez-LaRiviere, C., Pujos, M., Guell, A., & Houin, G. (1997). Pharmacology in space: Pharmacotherapy. In S. L. Bonting (Ed.), *Advances in space biology and medicine* (Vol. 6). Greenwich, CT: JAI Press.
16. Santy, P. A., Kapanka, H., Davis, J. R., & Stewart, D. F. (1988). Analysis of sleep on shuttle missions. *Aviation, Space, and Environmental Medicine, 59*, 1094–1097.
17. Aleksandrovskiy, Y. A., & Novikov, M. A. (1996). Psychological prophylaxis and treatments for space crews. In A. E. Nicogossian, S. R. Mohler, O. G. Gazenko, & A. I. Grigoriev (Eds.), *Space biology and medicine III: Humans in spaceflight, book 2*. Reston, VA: AIAA.
18. Saivin, S., Pavy-Le Traon, A., Soulez-LaRiviere, C., Guell, A., & Houin, G. (1997). Pharmacology in space: Pharmacokinetics. In S. L. Bonting (Ed.), *Advances in space biology and medicine* (Vol. 6). Greenwich, CT: JAI Press.
19. Santy, P. A. (1987). Psychiatric components of a health maintenance facility (HMF) on space station. *Aviation, Space, and Environmental Medicine, 58*, 1219–1224.
20. Kanas, N. (1998). Psychosocial training for physicians on board the space station. *Aviation, Space, and Environmental Medicine, 59*, 456–457.

4

Interpersonal Issues

Interpersonal problems relating to how space crewmembers interact with one another need to be addressed in order to improve the likelihood of mission success. Especially during long-duration space missions lasting more than six weeks, such issues take on an importance not found in shorter missions. The goals and activities of such missions are more complex and demand that the crewmembers form a cohesive group. In addition, interpersonal irritants that can be ignored for short durations become magnified and difficult to deal with during longer periods of time.

Group-level factors are not as easy to conceptualize as factors affecting individuals. For example, most people know what it means when an astronaut is feeling homesick or anxious, but less has been written about intra-crew tension or changes in cohesion over time. Many of these issues are by-products of normal small-group interactions and can be found in social and work groups on Earth. But, unlike on Earth, where people can leave a stressful group and take a walk or relax in a private setting, it is harder to escape a potentially toxic group environment in a space station or colony on a planetary body.

Interpersonal stressors resulting from human space missions relate to:

- interpersonal tension and loss of cohesion;
- personality conflicts;
- career motivation and life experiences;
- male–female differences;
- sexual tensions;
- withdrawal, territorial behavior, and privacy;
- subgrouping and scapegoating;
- displacement;
- leadership roles.

4.1 INTERPERSONAL TENSION AND LOSS OF COHESION

The ability of space travelers to work together in a cohesive manner is very important. Cohesion not only is necessary for crewmember well-being and routine work operations, but it is critical during times of crisis when the crew needs to respond as an efficient unit.

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_4

Proper selection of compatible crewmembers and adequate training to assure that they can work together effectively are important factors affecting cohesion.

Issues causing group tension also can decrease cohesion. We have seen in Chap. 1 that some studies have shown group cohesion to be negatively affected by time, especially shortly after the halfway point. However, in some groups, the opposite occurs, where tension decreases and cohesion improves as people adjust to one another. In a study of seven men and women participating in a 3-week Arctic scientific expedition, Palinkas and his colleagues [1] reported significantly higher tension levels prior to the start of the mission than during the mission itself, when the crewmembers seemed to adapt to their situation. Similarly, in a 135-day Mir space station simulation study on Earth, my colleagues and I [2] found significantly less tension during the last half of the isolation than during the first half, and there was significantly more tension in the group prior to entering the isolation chamber than after the mission began. Sometimes, extraneous factors lead to such improvement. In our Mir simulation study, subjects received replacement computer parts, favorite foods, and letters from home during a mid-mission resupply event, and this positive activity seemed to improve morale and cohesion.

We will now discuss a number of factors that may be associated with tension and decreased cohesion in a group under isolated and confined environment (ICE) conditions.

4.2 PERSONALITY CONFLICTS

One such factor relates to personality conflicts. In Sect. 2.1, we discussed personality characteristics that are suitable for space missions. Now we will look at characteristics that negatively impact on team behavior. For example, in one ground-based study measuring the effects of isolation and confinement, 36 sailors were given psychological tests and then were paired according to different conditions of compatibility [3]. Some pairs were isolated for 10 days in cabins, whereas others did the same tasks but went home in the evening. In the isolated condition, four pairs of men experienced interpersonal conflict, such as arguing and withdrawing from each other. In three of these pairs, both members were high in dominance on the Edwards Personal Preference Scale. Matched pairs in the non-isolated condition performed well and experienced no arguments, probably because they could escape from each other at night and diffuse any tension that occurred during their work time.

In another study, Sandal et al. [4] studied six crewmembers who participated in a 4-week European Space Agency (ESA) confinement study called ISEMSI (Isolation Study for European Manned Space Infrastructures). Tension was found between the two crewmembers rated as being most dominant, one of whom was the commander. The person who was not the commander became socially isolated from the other crewmembers, suggesting that personality incompatibility led to competition and interpersonal expulsion of this person from the group.

Gushin and his colleagues [5] evaluated three-person crews who participated in two space analog confinement studies in Moscow, one lasting 90 days and one lasting 135 days (which was called HUBES, or HUman BEhaviour Study). In both studies, the

crewmembers were unable to make their personal self-concepts become similar to their concepts about fellow crewmembers. The investigators interpreted this as suggesting problems with cohesion (which they called "disintegration"), with one member in each crew becoming an outsider.

4.3 CAREER MOTIVATION AND LIFE EXPERIENCES

Non-personality issues also can create tension in a group. An example relates to the career motivation and life experiences of the crewmembers. Gunderson [6] studied participants in five US Antarctic stations and found that, during the winter-over period, the naval personnel, who were used to being outside and active, experienced more psychological problems and interpersonal tensions than the civilians, who mostly were scientists and technicians comfortable with working indoors. Since the latter used the unstructured time to complete experiments and write up scientific reports, the confinement of winter-over allowed them to do their work and was more congruent with their career motivations and experiences than was the case for the naval personnel.

Sometimes, conflicts between scientists and non-scientists can lead to open hostilities. In one case involving a scientific expedition at sea, the scientists kept extending the mission in order to collect more data samples. In response, angry members of the homesick crew snuck into the refrigerator room one night and tossed laboriously collected study samples overboard [7]. It is important for groups of people with different work backgrounds and motivations to respect each other's roles and cooperate; otherwise, mission objectives may be compromised (Fig. 4.1).

4.4 MALE–FEMALE DIFFERENCES

There has been no evidence of male–female differences in terms of behavioral or psychological responses to spaceflight [8]. In 1996, an American female astronaut, Shannon Lucid, flew on orbit for over six months with two male Russian cosmonauts on the Mir space station. All three crewmembers performed their tasks and got along well with each other. Other male–female crews have flown for 6-month periods on the International Space Station (ISS), and anecdotal reports have suggested that there were no major problems. Women also have assumed the role of mission commander, such as Peggy Whitson in ISS Expedition 16 (Fig. 4.2).

Studies on Earth have demonstrated that women perform well in space simulation environments. For example, on a Tektite submersible mission, the performance of a crew of five women was judged to be equal to or better than that of all-male crews who participated in the project [9]. Kahn and Leon [10] evaluated an expedition team composed of four women that spent 67 days in the Antarctic. The investigators concluded that this team performed on a par with all-male or male–female teams.

Women can sometimes improve the group climate. Leon [11] concluded that all-male polar expedition teams showed patterns of strong competitiveness and little sharing of

4.1 Several American and Russian astronauts monitoring the docking of a resupply vehicle to the International Space Station (ISS). Space crewmembers of varying backgrounds must work together on essential mission activities. NASA/JSC digital image dated January 27, 2012

4.2 The International Space Station (ISS) Expedition 16 crewmembers, led by Commander Peggy Whitson. The mission terminated successfully on April 19, 2008. NASA image

personal concerns. In contrast, women in male–female groups and all-female teams exhibited considerable concerns about the welfare of their teammates. Wood and her colleagues [12] found that women in Antarctic stations were more sensitive than men to decrements in crew cohesion. In an ESA space simulation study called EXEMSI (Experimental Campaign for the European Manned Space Infrastructure), three men and one woman were isolated in a hyperbaric chamber for 60 days. The one female crewmember was seen as being a peacemaker who played an important role in lowering the overall tension in the group [13].

However, there are indications that interpersonal tensions may occur in male–female crews working in ICEs. For example, sexual stereotyping was reported during the 211-day Salyut 7 mission, when a newly arriving female cosmonaut was greeted with flowers and a blue floral print apron and was asked to prepare the meals [14]. Similar stereotyping was noted during the 61-day joint Soviet–American Bering Bridge expedition from Siberia to Alaska. During this mission, Leon and her colleagues [15] concluded that the Soviet men were more chauvinistic than their American counterparts toward the female expedition members. Rosnet et al. [16] found the presence of seductive behavior, rivalry, and sexual harassment in a polar station when the women were about the same age as the men. These studies suggest that attitudinal issues may affect male–female relationships in ICEs, even though intellectual or performance differences are negligible.

4.5 SEXUAL TENSIONS

The possibility of pairing off and engaging in sexual activities also needs to be considered as a factor in producing crew tension and disrupting group cohesion during long-duration space missions. In a space simulation project conducted in Moscow that involved several multinational teams (called SFINCSS, or Simulation of a Flight of International Crew on Space Station), a female participant reported unwanted sexual advances (including kissing) from a male participant. This resulted in group tension and a disruption in the group [17–19]. Stuster [20] found that similar unwanted sexual attention has occurred during Antarctic missions, and that disruptions in cohesion have taken place as a result of male–female pairings. He has pointed out that if a woman chooses to have a relationship, it often is with one man, with a preference for senior over junior personnel. One might argue that future space crews should consist of married couples or stable male–female pairs in order to minimize competition and conflict. However, there is no reason to expect that such a crew composition would prevent secret liaisons and jealousies, since infidelity and extramarital relations occur on Earth in less stressful interpersonal environments.

There have been no confirmed episodes of heterosexual (or, for that matter, homosexual) encounters in space, according to American and Russian astronauts and space experts [21, 22]. Although testosterone levels are lowered in microgravity, one male astronaut reported that during many of the days that he was in space, he and at least one other male colleague had an erection upon awakening [23]. A male space tourist reportedly had a similar experience [24].

One sexual performance issue that has drawn some attention concerns the ability of a couple to remain in intimate contact during sex in space, given the physical constraints of

microgravity on orientation and movement. Space experts believe that couples could adapt to this situation [21].

If sex does occur in space, it is important that women avoid pregnancy, since there is evidence from animal studies that fetal and neonatal development may be affected negatively by microgravity [25, 26]. Because many female astronauts take oral contraceptives during their mission to regulate menstrual cycle function and attenuate bone loss that can lead to osteoporosis [27], pregnancy for these women would be a low risk.

4.6 WITHDRAWAL, TERRITORIAL BEHAVIOR, AND PRIVACY

In his diary during a 211-day Salyut mission, cosmonaut Lebedev [14] described withdrawing from his crewmate. He blamed this on unspoken tension arising between the two men and a lack of stimulation as their mission dragged on. Withdrawal also has been observed in space analog environments [3, 13]. In its extreme, withdrawal can result in territorial behavior, where people become overly sensitive to the need for personal space and property, and where arguments and fights can result from minor intrusions. For example, borrowing someone's pen or sitting in his or her place during a meal can result in outrage, arguments, and even physical altercation. Such behavior, which is much more extreme than normal privacy concerns, may lead to major disruptions in performance and a drop in group cohesion.

Some separations are planned, such as when new members arrive or old members depart for Earth. Sometimes, these goodbyes can be emotional, as can occur on Earth when friends leave each other. During crewmember turnovers, it is important for the old members to orient the new ones to their new environment so that the transition is smooth and safe (Fig. 4.3).

Privacy concerns also are important. People living and working in small groups need to have time away from each other. The private space need not be large, just enclosed in some way so that a person perceives it as a retreat from the pressure of being with other people all the time. Privacy needs can be influenced by time as well as by cultural norms, as we shall see in Chap. 5.

4.7 SUBGROUPING AND SCAPEGOATING

Crew tension also can result from subgrouping, where crewmembers segregate along social, national, or job-oriented lines. Some subgrouping is normal in groups, since people like to associate with others based on common interests, hobbies, background, etc. If the subgroups do not interact with one another at least part of the time, it sets up the potential for misunderstandings and miscommunications that can negatively affect the mission. In its extreme, subgrouping may reflect deep divisions in a group of people and destroy their ability to perform as a unit.

For example, during the 12-man International Biomedical Expedition to the Antarctic [28, 29], subgroups formed along national lines. This resulted in crewmember irritability, aggressiveness, competition, and lack of mutual concern. In the Biosphere 2 isolation

4.3 Changeover of International Space Station (ISS) crews, as the new crewmembers say goodbye to those soon to depart for Earth. Change and farewells are part of current on-orbit space activities. NASA/JSC digital image dated September 15, 2011

experiment [30], the eight-person crew divided into two factions, each composed of two men and two women. One faction supported the management program and the other viewed it more negatively. Palinkas et al. [31] described a pattern of subgrouping in the Antarctic where crewmembers formed cliques based upon where in the station they spent most of their leisure time. They termed these divisions the "biomed," "library," and "bar" subgroups.

Sometimes, one person is singled out and blamed when a group of people cannot resolve an issue that leads to intra-group tension. Typically, this is a person who is most unlike the other crewmembers based on demographic or personality traits. He or she is "set up" to become the scapegoat, especially if this person espouses unpopular ideas. This especially can occur if only one person from an important subgroup is represented in a crew (e.g., one woman, one American, one scientist).

In ICEs, a scapegoated individual who is excluded from the group may experience a syndrome that in polar missions is called the "long-eye" phenomenon [32]. A person affected by this syndrome may stare off into space and experience dissociation, insomnia, depression, agitation, and psychosis (e.g., auditory hallucinations, persecutory delusions). These characteristics of the long-eye phenomenon may be transient and disappear once the excluded person is accepted back into the group. Scapegoating of an unpopular individual occurred during the International Biomedical Expedition to the Antarctic [29], and it also has been reported during hyperbaric chamber isolation studies [5].

4.8 DISPLACEMENT

One way of relieving group tension and improving cohesion is to direct interpersonal stress outwardly. People working for long periods of time in ICEs may direct or displace tension from their "in-group" to a convenient "out-group" that is more distant and less able to retaliate. Many people experience displacement at the individual level when they get angry with their boss but cannot confront him or her directly, then go home and yell at innocent bystanders, such as a spouse or a neighbor.

There have been reports from space analog studies that isolated individuals have become irrationally angry at outside people monitoring their behavior, especially during tense times when anger cannot be expressed between the confined crewmembers themselves [33–35]. Similar behavior occurred during the 60-day EXEMSI space simulation project [13] and during the 135-day Mir simulation study [2]. This suggests that what is happening is a displacement of intra-crew tension and negative dysphoric emotions to safer, more remote individuals on the outside.

Based on a review of early space analog studies, Bill Feddersen and I [36] predicted in 1971 that displacement also would be found in space crews. As space missions subsequently became longer and crews became more diverse, post-return debriefings and crewmember diaries suggested that this indeed was happening, with crews experiencing intra-group tension and displacing it outwardly to Mission Control. This created problems in communication and affected the ability of crews and ground personnel to work well with each other (Fig. 4.4) [14, 37–39].

4.4 Johnson Space Center Mission Control team members monitor a Space Shuttle flight. It is important for crewmembers and Mission Control personnel to communicate clearly and honestly with each during near-Earth missions. NASA/JSC digital image dated May 8, 1989

A vivid description of displacement in space was reported during the 211-day Salyut 7 mission. In his diary for this mission, crewmember Lebedev [14] reported that he felt increasing frustration with people on the ground, while at the same time he recorded on-board tension between himself and his fellow cosmonaut that was not overtly expressed or discussed between the two of them. Sometimes, this anger with the ground was related to a perceived change in the voice quality of people on Earth. In particular, Lebedev stated that a physician friend of his seemed to become more strident and sharper with him as the mission wore on, which puzzled and annoyed him since there was no rational explanation for this perceived change.

During the American 3-month Skylab mission, the crewmembers were under a lot of pressure to comply with a busy activity schedule, and they began to perceive members of Mission Control as being unsupportive. As crew-ground tensions increased, the crewmembers conducted a work stoppage, which was tantamount to a strike in space [38, 39]. After taking time off for a crew-ground "bull session," the tension was reduced and the schedule was modified. Such conflict between crewmembers and Mission Control could be catastrophic during a space mission, especially if it occurred during a crisis, and it is important for these two groups to continually monitor their interpersonal interactions.

By displacing their on-board problems to the outside, crewmembers may experience temporary relief. However, the sources of the problems are not dealt with. It would be better for crewmembers to identify the causes of intra-psychic and intra-group tension and to initiate strategies for coping with these causes directly. In this way, the stressors would not be allowed to fester, thus improving crewmember morale and well-being and reducing the chance of crew-ground communication difficulties. The same goes for Mission Control personnel, who may react to work pressures on the ground by displacing tension and unpleasant dysphoric emotions to management or even to the crewmembers in space.

The notion of displacement has received some empirical support. Based on earlier pilot work, my colleagues and I identified six tension and dysphoric mood subscales in the measures we used in our Mir and ISS studies, and we hypothesized that these subscale scores would correlate negatively with scores from a measure of perceived support from outside personnel in Mission Control. We reasoned that when crewmembers experienced higher-than-normal (for them) levels of group tension, they would deal with it by displacing their dysphoria outwardly to Mission Control staff, thus perceiving them as not being very supportive. As predicted, all six correlations were significant and in the predicted negative direction [40, 41].

Using versions of the same measures we used in our study that were adapted to Chinese subjects, Wu and Wang [42] studied three subjects participating in the Lunar Palace 1 lunar station simulator in Beijing. They found that the same six tension and mood subscales we used to test for displacement correlated in the same predicted negative direction with a measure of perceived support from the outside. Four of the six correlations were statistically significant, one was borderline significant, and the last was not significant but was in the predicted direction. Considering that they only studied one group of three subjects, this close approximation to our findings suggested that our operational definition of displacement is robust and reproducible using the same psychological instruments, even in a non-Western Chinese population.

In Russia, Gushin and his colleagues studied cohesion and in-group/out-group conflicts in isolated groups located both on the ground and in space using an analysis of speech patterns. They found that over time, the crewmembers showed decreases in the scope and content of their communications and a filtering in what they said to outside personnel, which was termed "psychological closing" [43, 44]. Sometimes, this served to hide medical and psychological problems in the crew. The subjects also withdrew into themselves and became more egocentric—a process the investigators called "autonomization." In a displacement-like manner, these factors resulted in some members of Mission Control being perceived negatively as opponents. This research team also found that crewmembers became more cohesive by spending time together (including joint birthday celebrations) [45], and that the presence of subgroups and outliers (e.g., scapegoats) negatively affected group cohesion [5].

Stuster [46] examined a number of interpersonal issues affecting crewmembers in space who were living and working on orbit. He conducted a content analysis of personal journals from 10 ISS astronauts that focused on a number of issues that had behavioral implications. Eighty-eight percent of the entries dealt with the following categories: Work, Outside Communications, Adjustment, Group Interaction, Recreation/Leisure, Equipment, Events, Organization/Management, Sleep, and Food. The crewmembers reported that living in space with their colleagues was not as difficult as they had expected prior to launch. However, a 20 % increase in interpersonal problems was recorded during the second half of the missions. Stuster concluded that interpersonal tensions occur in space and may become worse as the mission wears on. He recommended that crewmembers be allowed to control their individual schedules as much as possible as a way of dealing with the stressors of space travel, as opposed to having all their activities directed by people in Mission Control.

4.9 LEADERSHIP ROLES

In our Mir and ISS studies, my colleagues and I took a look at the impact of leadership roles on group cohesion. We predicted that subscale scores related to the task and support roles of the leader (mission commander for the crewmembers, team leader for the Mission Control subjects) would both correlate positively to a group cohesion subscale. We found this to be the case for the Mission Control subjects. Although crewmember scores showed a similar significant relationship between the support role of the mission commander and crew cohesion, they did not show a significant relationship between the task role of the commander and cohesion.

Wu and Wang [42] replicated these results in their Lunar Palace 1 study. Like us, they found a positive and significant correlation between a measure of leader support and cohesion, but not between a measure of the task role of the leader and cohesion.

The finding of a relationship between leader support and cohesion but not between the task role of the leader and cohesion in people working in space might have been an artifact of crew size. The on-orbit crews that we studied consisted of only two or three people and, in such a crew, each person has specialized job skills that make him or her a unique leader in those areas that are related to these skills. For example, the commander might focus on

piloting and navigation, whereas the engineer might specialize in equipment maintenance and repair. So, when a piece of equipment breaks down, the commander might defer to the skill and judgment of the engineer, even though the former is the responsible task leader. Wu and Wang cited a similar reason for their results.

REFERENCES

1. Palinkas, L. A., Suedfeld, P., & Steel, G. D. (1995). Psychological functioning among members of a small polar expedition. *Aviation, Space, and Environmental Medicine, 66*, 943–950.
2. Kanas, N., Weiss, D. S., & Marmar, C. R. (1996). Crew member interactions during a Mir space station simulation. *Aviation, Space, and Environmental Medicine, 67*, 969–975.
3. Haythorn, W. W., & Altman, I. (1963). *Alone together. Research task MR022-01-03-1002*. Washington, DC: Bureau of Medicine and Surgery/US Navy Department.
4. Sandal, G. M., Vaernes, R., & Ursin, H. (1995). Interpersonal relations during simulated space missions. *Aviation, Space, and Environmental Medicine, 66*, 617–624.
5. Gushin, V. I., Efimov, V. A., Smirnova, T. M., Vinokhodova, A. G., & Kanas, N. (1998). Subject's perceptions of the crew interaction dynamics under prolonged isolation. *Aviation, Space, and Environmental Medicine, 69*, 556–561.
6. Gunderson, E. K. E. (1968). Mental health problems in Antarctica. *Archives of Environmental Health, 17*, 558–564.
7. Finney, B. (1991). Scientists and seamen. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
8. NASA News Report (2014). Study investigates how men and women adapt differently to spaceflight. Retrieved November 17, from www.nasa.gov/content/men-women-spaceflight-adaptation/
9. Miller, J. W., Van Derwalker, I. G., & Waller, R. A. (1971). *Tektite 2: Scientists-in-the-sea*. Washington, DC: US Department of Interior.
10. Kahn, P. M., & Leon, G. R. (1994). Group climate and individual functioning in an all-women Antarctic expedition team. *Environment and Behavior, 26*, 669–697.
11. Leon, G. R. (2005). Men and women in space. *Aviation, Space, and Environmental Medicine, 76*(6, Suppl.), B84–B88.
12. Wood, J., Schmidt, L., Lugg, D., Ayton, J., Phillips, T., & Shepanek, M. (2005). Life, survival, and behavioral health in small closed communities: 10 years of studying isolated Antarctic groups. *Aviation, Space, and Environmental Medicine, 76*(6, Suppl.), B89–B93.
13. Vaernes, R. J. (1993). *EXEMSI'92 executive summary. NUTEC report 16–03*. Paris, France: European Space Agency Long Term Programme Office.
14. Lebedev, V. (1988). *Diary of a cosmonaut: 211 days in space*. College Station, TX: Phytoresource Research Information Service.
15. Leon, G. R., Kanfer, R., Hoffman, R. G., & Dupre, L. (1994). Group processes and task effectiveness in a Soviet–American expedition team. *Environment and Behavior, 26*, 149–165.
16. Rosnet, E., Jurion, S., Cazes, G., & Bachelard, C. (2004). Mixed-gender groups: Coping strategies and factors of psychological adaptation in a polar environment. *Aviation, Space, and Environmental Medicine, 75*(7, Suppl.), C10–C13.
17. Inoue, N., Matsuzaki, I., & Ohshima, H. (2004). Group interactions in SFINCSS-99: Lessons for improving behavioral support programs. *Aviation, Space, and Environmental Medicine, 75*(7, Suppl.), C28–C35.
18. Kass, R., & Kass, J. (2001). Team-work during long-term isolation: SFINCSS experiment GP-006. In V. M. Baranov (Ed.), *Simulation of extended isolation: Advances and problems*. Moscow, Russia: Firm Slovo.
19. Sandal, G. M. (2004). Culture and tension during an International Space Station simulation: Results from SFINCSS'99. *Aviation, Space, and Environmental Medicine, 75*(7, Suppl.), C44–C51.
20. Stuster, J. (1996). *Bold endeavors: Lessons from polar and space exploration*. Annapolis, MD: Naval Institute Press.

21. Karash, Y. (2000). Sex in space: From Russia … with love. *Space.com. Retrieved* March 16, from http://web.archive.org/web/20080710053017/http://www.space.com/scienceastronomy/generalscience/russian_sex_studies_000316.html
22. Wall, M. (2011). Russian official says there's been no sex in space … yet. *NBCNews.com.* Retrieved April 23, from www.nbcnews.com/id/42731409/ns/*technology_and_science-space/*
23. Mullane, M. (2006). *Riding rockets: The outrageous tales of a space shuttle astronaut*. New York: Scribner.
24. Woodmansee, L. S. (2006). *Sex in space*. Burlington, ON: CG Publishing.
25. Committee for the Decadal Survey on Biological and Physical Sciences in Space. (2011). *Recapturing a future for space exploration*. Washington, DC: Space Studies Board, National Research Council/The National Academies Press.
26. Clement, G. (2005). *Fundamentals of space medicine*. El Segundo, CA: Microcosm Press.
27. Ball, J. R., & Evans, C. H., Jr. (Eds.) (2001). Safe passage: Astronaut care for exploration missions. In: *Committee on creating a vision for space medicine during travel beyond earth orbit*. Institute of Medicine. Washington, DC: National Academy Press.
28. Rivolier, J., Cazes, G., & McCormick, I. (1991). The International Biomedical Expedition to the Antarctic: Psychological evaluations of the field party. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
29. Taylor, A. J. W. (1991). The research program of the International Biomedical Expedition to the Antarctic (IBEA) and its implications for research in outer space. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
30. Walford, R. L., Bechtel, R., MacCallum, T., Paglia, D. E., & Weber, L. J. (1996). "Biospheric medicine" as viewed from the two-year first closure of Biosphere 2. *Aviation, Space, and Environmental Medicine, 67*, 609–617.
31. Palinkas, L. A., Gunderson, E. K. E., Johnson, J. C., & Holland, A. W. (2000). Behavior and performance on long-duration spaceflights: Evidence from analogue environments. *Aviation, Space, and Environmental Medicine, 71*(9, Suppl.), A29–A36.
32. Rohrer, J. H. (1958). *Some impressions of psychic adjustment for polar isolation*. Washington, DC: Bureau of Medicine and Surgery/US Navy Department.
33. Dunlap, R. D. (1965). *The selection and training of crewmen for an isolation and confinement study in the Douglas space cabin simulator No. 3446* (pp. 1–52). Santa Monica, CA: Douglas Aircraft.
34. Jackson, J. K., Wamsley, J. R., Bonura, M. S., & Seeman, J. S. (1972). *Program operational summary: Operational 90-day manned test of a regenerative life support system* (NASA CR-1 835). Washington, DC: NASA
35. McDonnell, D. (1968). *60-Day manned test of a regenerative life support system with oxygen and water recovery. Part II: Aerospace medicine and man-machine test results. NASA CR-98501*. Santa Monica, CA: McDonnell Douglas Astronautics.
36. Kanas, N., & Feddersen, W. E. (1971). *Behavioral, psychiatric, and sociological problems of long-duration space missions. NASA TM X-58067*. Houston, TX: JSC/NASA.
37. Linenger, J. M. (2000). *Off the planet: Surviving five perilous months aboard the space station Mir*. New York: McGraw-Hill.
38. Belew, L. F. (1977). *Skylab, our first space station. NASA SP-400*. Washington, DC: National Aeronautics and Space Administration.
39. Cooper, H. S. F., Jr. (1976). *A house in space*. New York: Holt, Rhinehart & Winston.
40. Kanas, N., Salnitskiy, V., Weiss, D. S., Grund, E. M., Gushin, V., Kozerenko, O., et al. (2001). Crewmember and ground personnel interactions over time during Shuttle/Mir space missions. *Aviation, Space, and Environmental Medicine, 72*, 453–461.
41. Kanas, N. A., Salnitskiy, V. P., Boyd, J. E., Gushin, V. I., Weiss, D. S., Saylor, S. A., et al. (2007). Crewmember and mission control personnel interactions during International Space Station missions. *Aviation, Space, and Environmental Medicine, 78*, 601–607.
42. Wu, R. & Wang, Y. (2014). Psychosocial interaction during a 105-day isolated mission in LUNAR PALACE 1. IAC-14-A1.1.2. In: *65th International Astronautical Congress, Toronto, ON, Canada*.

43. Gushin, V. I., Zaprisa, N. S., Kolinitchenko, T. B., Efimov, V. A., Smirnova, T. M., Vinokhodova, A. G., et al. (1997). Content analysis of the crew communication with external communicants under prolonged isolation. *Aviation, Space, and Environmental Medicine, 68*, 1093–1098.
44. Kanas, N., Sandal, G., Boyd, J. E., Gushin, V. I., Manzey, D., et al. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64*, 659–677.
45. Gushin, V. I., Pustynnikova, J. M., & Smirnova, T. M. (2001). Interrelations between the small isolated groups with homogeneous and heterogeneous composition. *Human Performance in Extreme Environments, 6*, 26–33.
46. Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals. Experiment 01-E104 (Journals): Final Report.* NASA/TM-2010-216130. Houston, TX: NASA/Johnson Space Center.

5

Culture and Language Issues

Increasingly, manned space missions are becoming cross-cultural and multinational, with members from various national and ethnic groups comprising the crew and Mission Control, and equipment and structural parts from many nations comprising the space vehicles and habitats [1]. This trend toward cultural heterogeneity likely will continue in the future, so it is important to examine the impact of culture on space crewmembers.

Cultural differences produce many challenges for a space crew. For example, differences in personality styles can occur within any space crew, but the effects are more complicated if the crew also is multicultural. This is because some characteristics, such as emotional expressivity, may be common in some cultures but relatively unusual in others. In addition, psychiatric issues may manifest themselves differentially across cultural groups. For example, as we shall see below, depressed mood may be more likely to co-occur with anxiety among Americans but with fatigue among Russians. Third, cognitive and decision-making styles, along with individual behavioral norms such as privacy expectations and personal grooming habits, may vary by culture. Fourth, cultural differences in social behavioral norms, such as the expectation that everyone socialize together at mealtime, can lead to crew tension and cohesion during missions. Finally, culturally diverse crews introduce language issues that themselves can cause problems for space crewmembers. For example, international missions may suffer when there are the participants who are not fluent in a common language or where accents and other dialect differences interfere with good communication.

But cultural diversity is not all bad in that it adds to the crew's behavior and performance repertoire (Fig. 5.1). Although producing some stress early in a mission, differences among crewmembers can become an asset later on when monotony and homesickness can occur, and people seek out novel ideas and new relationships.

5.1 ASPECTS OF CULTURE IN MANNED SPACE MISSIONS

Helmreich [2] has examined culture with reference to aviation and medical communities as space analogs. He has concluded that there are three aspects of culture that are relevant to space missions: national, organizational, and professional. With reference to the first,

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_5

5.1 Space crews on long-duration space missions like the International Space Station (ISS) tend to be heterogeneous in terms of male–female, ethnic and racial background, and national origin, and this may have psychological ramifications In this ISS crew, members are from the US, Russia, and Europe. NASA/JSC digital image dated November 20, 2009

space crewmembers will have different ethnic backgrounds, nationalities, and native languages. This may lead to differences in behavior. Many of these are obvious, but others are more subtle. For example, people from Mediterranean countries typically are behaviorally animated and comfortable being physically close to others when speaking, whereas people from Northern European countries are more reserved and have less tolerance for people gesticulating close to them—behavior they may perceive as boorish or aggressive. When misconstrued, national cultural differences may be seen as a personal affront, disinterest, or simply as an annoyance, and this may lead to interpersonal or group tension.

The second aspect of culture pertains to features of the employment organization of which the individual is a member. In terms of international space missions, participating countries may have their own national space agencies with different goals and “macrocultures” that affect the way they do business [3]. For example, NASA tends to train their astronauts to deal with a variety of possible contingencies in preparation for their missions, whereas the Russian Federal Space Agency tends to focus on the major issues and to rely on the use of experts to resolve problems that might occur (Fig. 5.2). In addition, astronauts are paid a fixed salary for their duties, whereas cosmonauts receive a variable salary based on their performance in space. Such differences in organizational philosophy can affect how crewmembers from different space agencies behave on the job and interact with one another.

The final aspect of culture is related to one’s profession, discipline, experiences, or career motivation. Some space travelers come from piloting or engineering backgrounds, and their mission tasks are related to flying and vehicle maintenance. Others come from scientific backgrounds, and their tasks are related to conducting experiments and performing

5.2 People working in Mission Control also may be from different national space agencies, with their own unique policies and procedures. Here, a group of Russian flight controllers are taking part in a joint activity with their American counterparts at the NASA/JSC Mission Control Center. NASA/JSC digital image dated March 20, 1975

5.3 A mission specialist conducts a skin test on a Space Shuttle pilot as part of a science experiment. Crewmembers from different professional backgrounds must interact with each other to accomplish mission goals. NASA/JSC digital image dated April 29, 1990

non-operational duties. People from such groups have different professional norms, values, and traditions, and it is important that these be understood and amalgamated so that the crew operates cohesively as a unit to accomplish mission goals. Many space missions have been composed of piloting astronauts and mission specialists who must get along for the good of their mission despite different professional priorities and training (Fig. 5.3).

5.2 CULTURAL ISSUES IN SPACE: ANECDOTAL REPORTS

Bluth [4] has described a number of cultural traits that could create problems in space. For example, people from Arabic and Japanese cultures accept physical closeness better than Americans, and they might tolerate the cramped quarters of a space station better than their Western counterparts. Raybeck [5] has written about a number of national and cultural traits which affect one's concept of privacy. He states that in some cultures, people who prefer to be alone are regarded with suspicion or are seen as being deviant and nonconforming to the group norms. Such attitudes may influence the conception of one's self and one's relationship with others. He warns that such issues need to be addressed in planning for missions involving people working in confined environments for prolonged periods of time, such as in space stations. Along these lines, Pollis [6] has pointed out that there is no word for "privacy" in the Greek language, possibly reflecting the idea that existence apart from family and friends is foreign to Greek cultural norms. Consequently, an astronaut from Greece might perceive a fellow crewmember's desire for privacy as a personal affront rather than as a need to engage in solitary activity.

National and organizational issues can have an impact on space crews. During a Russian-operated Salyut 6 mission, a Czech "guest" cosmonaut joked that his hands turned red in space, since whenever he reached for a switch or dial, one of the Russian cosmonauts would slap his hand away and tell him not to touch anything [7]. During his Salyut 7 mission, cosmonaut Lebedev [8] wrote in his diary that he felt discomfort at having a French visiting cosmonaut on board in contrast to feeling more relaxed with Russian visitors two months later. During his 115-day visit to the Mir space station, astronaut Norm Thagard reported feeling culturally isolated as the only American on board with two Russian cosmonauts [9].

5.3 CULTURAL ISSUES IN SPACE: EMPIRICAL FINDINGS

There have been a number of studies that have taken a look at the impact of culture in the space environment. One of the first was conducted in 1992 at McDonnell Douglas and involved a survey of 74 individuals from NASA, the European Space Agency (ESA), the Canadian Space Agency (CSA), and the Japanese National Space Development Agency (NASDA) by means of a "Multicultural Crew Factors Questionnaire" [10]. As a result of this study, 14 key cultural and interpersonal communication factors were identified that could impact on multicultural crew operations and interactions. These included such factors as common language, nonverbal communication, respect for other cultures, and interpersonal interest and tolerance.

Santy and her colleagues [11] surveyed nine American astronauts who had flown on international space missions and recorded 17 incidents of miscommunication, misunderstanding, or interpersonal conflict that affected their mission. All of the respondents said that it was important to have pre-flight training in cultural issues.

Tomi et al. [12] surveyed 75 astronauts and cosmonauts and 106 Mission Control personnel, with a goal of assessing possible intercultural issues that might lead to misunderstandings and conflict during space missions. Both crewmember and Mission Control

subjects rated coordination problems between member organizations involved with the missions as being the most important issue, followed by communication difficulties due to simple misunderstandings. Other problem areas related to differences in language and work management styles, and communication difficulties between Mission Control personnel and their support teams. The subjects felt that the most important countermeasure for dealing with these problems involved cross-cultural training of astronauts and Mission Control personnel, and over 83 % of the survey respondents stated that this training should involve key members of both groups training together in order to encourage team-building.

Sandal and Manzey [13] surveyed 576 employees of ESA, with the goal of examining important cultural issues that might impact on performance, both within ESA and between ESA and other space agencies. They found a connection between cultural diversity and challenges pertinent to human interactions that could interfere with work efficiency. Especially important were factors related to leadership issues and the decision-making process. The investigators concluded that cross-cultural training was an important countermeasure to deal with such diversity, both within ESA and between ESA and other space program teams.

In our Mir and International Space Station (ISS) studies, my colleagues and I [14, 15] examined the results to look for possible cultural differences between American and Russian subjects. We found that compared with the Russians, the Americans reported significantly more work pressure in both Mir and ISS missions and less tension during ISS missions (this also was the case during Mir missions, but the difference was not statistically significant). We concluded that these findings may have reflected both national differences (i.e., the Americans might have felt more pressure to perform than the Russians due to on-the-job expectations rooted in typical American attitudes about competition and achievement) and space agency organizational differences (i.e., the American astronauts might have experienced more work pressure than their Russian colleagues as they tried to deal with various agency-directed procedural activities in a timely manner during both Mir and ISS missions). The relative anxiety felt by the Russian crew and ground subjects may have reflected their lack of familiarity with American operational tasks and procedures.

In the ISS study, my colleagues and I [15] included a Culture and Language Questionnaire that was specifically designed for participants in a multinational space program. The ISS crewmembers scored higher in cultural sophistication than Mission Control personnel, which might be expected, since they trained in various locations and as a result interacted more with people from other countries. American Mission Control personnel scored lower than their Russian counterparts, which was a bit surprising given the diversified nature of US culture and the relative financial ability of Americans to travel. Perhaps this finding reflected the physical proximity of Russia to other Asian and European countries, especially to centers of the multinational ESA, with whom Russia has worked on a number of projects.

My colleague, Jennifer Boyd, and I wondered if there would be differences in patterns of mood states that were exhibited by American and Russian crewmembers. The reasoning was that in the Russian culture, where asthenia is accepted as a syndrome, there would be an association between depressed mood and fatigue, since these two states should co-vary according to the asthenia model (see Sect. 2.4). In contrast, in the American culture,

depression might be expected to co-vary with anxiety, which would be predicted according to the model of reactive depression based on early life anxiety-producing conflicts and deprivations that has been used in the US and in Europe.

In the combined Mir and ISS crewmember sample (13 astronauts and 17 cosmonauts), we found that as predicted for the Russians, measures of depression and fatigue were significantly related, whereas the relationship between depression and anxiety was not significant [16, 17]. For the Americans, again as predicted, the relationship between depression and anxiety was significant, whereas the relationship between depression and fatigue was not. It should be noted that in both cultural groups, depression scores were not high enough to be considered clinically meaningful. Both groups associated depression with anger, which makes sense since irritability is a common feature of both cultures' models of distress. These findings suggest that patterns of mood states in crewmembers may reflect national cultural norms, and further work in this interesting area needs to be done.

5.4 LANGUAGE AND DIALECT VARIATIONS

5.4.1 Native Language Versus Space Terminology

When crewmembers are fluent in different languages, their perceptions of the interpersonal environment can be affected. For example, astronaut Norm Thagard commented that he felt socially and culturally isolated during his Mir mission and that this was related to the fact that he was the only native English speaker on board. His fellow crewmembers were Russian cosmonauts, and Thagard sometimes went up to 72 h without speaking to anyone in his native language [9]. Astronauts have stated that conversational language training in the native languages of people on board are important in missions involving international crews [11].

Language differences also have been found to affect crewmember interactions in space analog environments on Earth. For example, language differences were implicated in the group disintegration that was observed during the SFINCSS project [18]. Although English was the official language, it was not native for some of the participants. The lack of premission language training, along with differences in communication styles, interfered with effective communications between one of the groups and outside monitors.

In their survey of 54 astronauts and cosmonauts who had flown in space, Kelly and Kanas [19] found that all of the respondents acknowledged that it was important for space crewmembers to be fluent in a common language, and 63 % believed that it was very important. Astronauts scored significantly higher than cosmonauts on a scale rating the importance of a common language, and pilots and commanders scored significantly higher than researchers on this scale. This last finding may have reflected the concern of pilots and commanders that people communicate clearly while performing tasks of vital operational importance, especially during emergencies. In terms of dialect, international astronauts participating in US missions rated the importance of speaking a common dialect significantly lower than their American and Russian counterparts. This may have been due to the fact that most of the internationals were European and may have been exposed to

more languages in their lifetimes. Crew communication was judged to be enhanced by a sense the respondents had of undergoing a shared common experience during their space missions.

Native language is not the only linguistic issue related to space missions. Astronauts and cosmonauts also must be familiar with the specialized space terminology that is used during a mission, and even this can vary [20]. For example, NASA space terminology is derived from basic English and includes a set of synonyms, acronyms, and neologisms related to this language. In contrast, Russian space terminology has a different set of linguistic parameters. However, there are also commonalities, and for some, the space language is easier to master than a non-native language. It is possible that in time, a universal space language will evolve that will transcend the peculiarities of any single national language, especially as a result of multinational space missions.

5.4.2 Problems Related to Language and Dialect Variations

Linguistic differences can lead to crew miscommunications. This may create serious problems during crises and emergencies, where the need for prompt and integrated crew response is paramount in an environment producing anxiety and confusion. It is most problematic for people where the common mission language is not their native language. But subtle miscommunications can occur among people speaking the same native language as well. During his 175-day Salyut 6 mission, Valeri Ryumin wrote in his diary that comments uttered between him and his fellow Russian crewmember sometimes took on special meaning, and even the tone was important [21]. He found it necessary to consider the consequences of his words in case some miscommunication occurred that might have been offensive or unclear to his crewmate. He also found that in space, neither he nor his fellow cosmonaut was talkative, and most of their communications related to accomplishing the goals of the mission.

On the Culture and Language Questionnaire used during our ISS study that was referred to above, my colleagues and I found that Americans scored significantly higher than Russians on the importance of all crewmembers and Mission Control personnel speaking the same dialect of a common language during space missions. Russians involved with international space activities are probably exposed to English more than Americans are to Russian, since most conferences and meetings involving ISS partners are conducted in the English language (as are US movies and television programs that are widely transmitted abroad). This familiarity might have accounted for the greater language flexibility endorsed by the Russian subjects.

REFERENCES

1. Kanas, N., Sandal, G., Boyd, J. E., Gushin, V. I., Manzey, D., et al. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64*, 659–677.
2. Helmreich, R. L. (2000). Culture and error in space: Implications from analog environments. *Aviation, Space, and Environmental Medicine, 71*(9, Suppl.), A133–A139.
3. Committee on Space Biology and Medicine; Space Studies Board; Commission on Physical Sciences, Mathematics, and Application; National Research Council. (1998). *A strategy for research in space biology and medicine in the New century*. Washington, DC: National Academy Press.

4. Bluth, B. J. (1984). The benefits and dilemmas of an international space station. *Acta Astronautica, 11*, 149–153.
5. Raybeck, D. (1991). Proxemics and privacy: Managing the problems of life in confined environments. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
6. Pollis, A. (1965). Political implications of the modern Greek concept of self. *British Journal of Sociology, 16*, 29–47.
7. Oberg, J. E. (1981). *Red star in orbit*. New York: Random House.
8. Lebedev, V. (1988). *Diary of a cosmonaut: 211 days in space*. College Station, TX: Phytoresource Research Information Service.
9. Benson, J. (1996, January). Conversations with Norman Thagard. *Aerospace America*, 12–14.
10. Lozano, M. L., & Wong, C. (1996). Concerns for a multicultural crew aboard the international space station. *CSERIAC Gateway, 7*, 1–4.
11. Santy, P. A., Holland, A. W., Looper, L., & Marcondes-North, R. (1993). Multicultural factors in the space environment: Results of an international shuttle crew debrief. *Aviation, Space, and Environmental Medicine, 64*, 196–200.
12. Tomi, L., Kealey, D., Lange, M., Stefanowska, P., & Doyle, V. (2007, May 21). Cross-cultural training requirements for long-duration space missions: Results of a survey of International Space Station astronauts and ground support personnel. *Paper delivered at the Human Interactions in Space Symposium, Beijing, China*.
13. Sandal, G. M., & Manzey, D. (2009). Cross-cultural issues in space operations: A survey study among ground personnel of the European Space Agency. *Acta Astronautica, 65*, 1520–1529.
14. Kanas, N., Salnitskiy, V., Grund, E. M., Gushin, V., Weiss, D. S., Kozerenko, O., et al. (2000). Interpersonal and cultural issues involving crews and ground personnel during Shuttle/Mir space missions. *Aviation, Space, and Environmental Medicine, 71*(9 Suppl.), A11–A16.
15. Boyd, J. E., Kanas, N. A., Salnitskiy, V. P., Gushin, V. I., Saylor, S. A., Weiss, D. S., et al. (2009). Cultural differences in crewmembers and Mission Control personnel during two space station programs. *Aviation, Space, and Environmental Medicine, 80*, 1–9.
16. Ritsher, J. B. (2005). Cultural factors and the International Space Station. *Aviation, Space, and Environmental Medicine, 76*(6, Sect. II), B135–B144.
17. Boyd, J. E., Kanas, N., Gushin, V. I., & Saylor, S. (2007). Cultural differences in patterns of mood states on board the International Space Station. *Acta Astronautica, 61*, 668–671.
18. Gushin, V. I., & Pustinnikova, J. M. (2001). Mutual perception in national and international groups under prolonged isolation. In V. M. Baranov (Ed.), *Simulation of extended isolation: Advances and problems*. Moscow: Firm Slovo.
19. Kelly, A. D., & Kanas, N. (1992). Crewmember communication in space: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 63*, 721–726.
20. Peeters, W., & Sciacovelli, S. (1996). Communication related aspects in multinational missions: Euromir 94. *Journal of the British Interplanetary Society, 49*, 113–120.
21. Chaikin, A. (1985, February). The loneliness of the long-distance astronaut. *Discover 1985,* 20–31.

6

Positive Effects of Space

Up until now, we have considered some of the stressful aspects of space travel. However, traveling in space has many positive aspects as well, and for some it can be growth-enhancing. Many space travelers have returned home with a more positive view of themselves and their place on the planet. Earth can be seen as a beautiful and unique place, without obvious political boundaries or reasons for national strife (Fig. 6.1). Some astronauts and cosmonauts in space have reported transcendental experiences, religious insights, or a better sense of the unity of humankind as a result of viewing Earth below and the cosmos beyond [1, 2]. In his diary, cosmonaut Valentin Lebedev [3] stated that his Earth photography experiences on the Salyut 7 space station were restful and positive, and he hoped that they would help him gain an advanced degree after he returned from his 211-day mission (Fig. 6.2).

At times, preoccupation with the enchantment of space has caused problems during space missions. For example, one Salyut 6 cosmonaut became so enraptured with his view of the heavens that he began to float out of an open air lock without attaching his safety line [4], and an astronaut perturbed the gyroscopic system of the Skylab orbiting facility when he left his workstation to get a better view of Earth [5]. But most positive experiences in space have not been so harrowing. Let's take a closer look at some of the characteristics of such experiences.

6.1 SALUTOGENESIS

The concept of salutogenesis refers to the health-promoting, growth-enhancing effects of a challenging situation. Some individuals gain strength and wisdom from successfully coping with a personal crisis; hence, negative stressors can produce positive change [6, 7]. Positive stressors can bring about positive change as well, especially when the positive experience is deliberately sought out.

Larry Palinkas [8] and Peter Suedfeld [9] have discussed the salutogenic reactions some people have to the adverse conditions found in polar environments. For example, some returning explorers have experienced increased fortitude, perseverance, independence, self-reliance, ingenuity, and comradeship while on the ice. Suedfeld [10, 11] has

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_6

6.1 As seen rising above the lunar surface, Earth presents as a beautiful, almost mystical, entity floating in space which is devoid of political boundaries or international strife. NASA image taken from Apollo 8 on December 24, 1968

6.2 A mission specialist examines her camera equipment during a Space Shuttle mission. Although photographs of Earth and other objects in space are often part of the mission objectives, some astronauts have developed an interest in photography as a result of this activity. NASA/JSC digital image dated January 20, 1990

argued further that we should pay more attention to positive psychology and salutogenesis in planning for future space missions. He and his colleagues [12] found that 20 retired male Mir and International Space Station (ISS) cosmonauts reported a number of positive changes on measures of personal growth as a result of flying in space. When compared with two groups on Earth who had experienced stressful events—first-time mothers and trauma survivors—the cosmonauts especially scored highly in the domains of realizing new possibilities and personal strength. Those who had spent more than a year in space, and those who had flown on both Mir and the ISS were more likely to report positive change in their appreciation of life.

The retired cosmonauts also were evaluated for coping strategies they found effective in dealing with the stress of being in space. It was found that they preferred problem-oriented coping strategies rather than emotion-oriented ones. The three most mentioned coping strategies were seeking social support, planful problem solving, and persevering to meet the mission demands [13].

Some space travelers have experienced changes in core values as a result of flying in space. Suedfeld and his colleagues [14] conducted a thematic analysis of the values and emotions mentioned by four pioneering astronauts. Three of the four reported an increase in the value of a measure of universalism (i.e., a greater appreciation for other people and nature), both during and after their mission, and all four reported an increase in spirituality post return. This study was followed up by a content analysis of the published memoirs of 125 American and Russian space travelers [15]. The investigators again found that as a result of being in space, astronauts and cosmonauts reported positive changes in measures of universalism and spirituality, as well as an increase in power. Cultural differences were found. For example, Russian space travelers scored higher in measures of achievement and universalism and lower in enjoyment than Americans. Using the same methodology, Brcic and Della-Rossa [16] found universalism to be high and enjoyment low in the public records of Canadian astronauts who had been in space. Achievement, security, and self-direction also were frequently mentioned as being important values.

Vinokhodova and Gushin [17] studied 12 ISS cosmonauts using the Personal Self Perception and Attitudes (PSPA) psychosocial test in order to assess their attitudes toward their social environment (both within the crew and with Mission Control). The investigators also performed a content analysis of the subjects' communications to examine their interpersonal perceptions. The results indicated that the cosmonauts' system of values and personal attitudes mostly remained stable as a result of flying in space. The most valuable personal traits were those that led to the successful fulfillment of the cosmonauts' professional activities as well as helping them achieve positive social relationships.

6.2 POSITIVE ASPECTS OF SPACE

In a Mars mission simulation taking place in Moscow, six crewmembers were isolated and confined for 520 days (see Sect. 10.2). Solcova et al. [18] studied the affective processes of the crew using mood questionnaires and a semi-structured post-mission interview. They found that the crewmembers predominately reported having positive emotions throughout the mission. Changes in mood were asynchronous and balanced. The results suggested

that, unlike in their everyday life, the crewmembers were replacing negative feelings with emotions that had a positive valence.

My colleagues and I also have been interested in the positive aspects of manned space missions. In one survey of 54 astronauts and cosmonauts who had flown in space, Kelly and Kanas found that the subjects rated the positive excitement related to their mission as being one of the strongest factors enhancing communication within the crew [19] and between the crewmembers and Mission Control personnel on the ground [20]. This is important, since good communication is essential for crew safety and mission success during long-duration on-orbit missions.

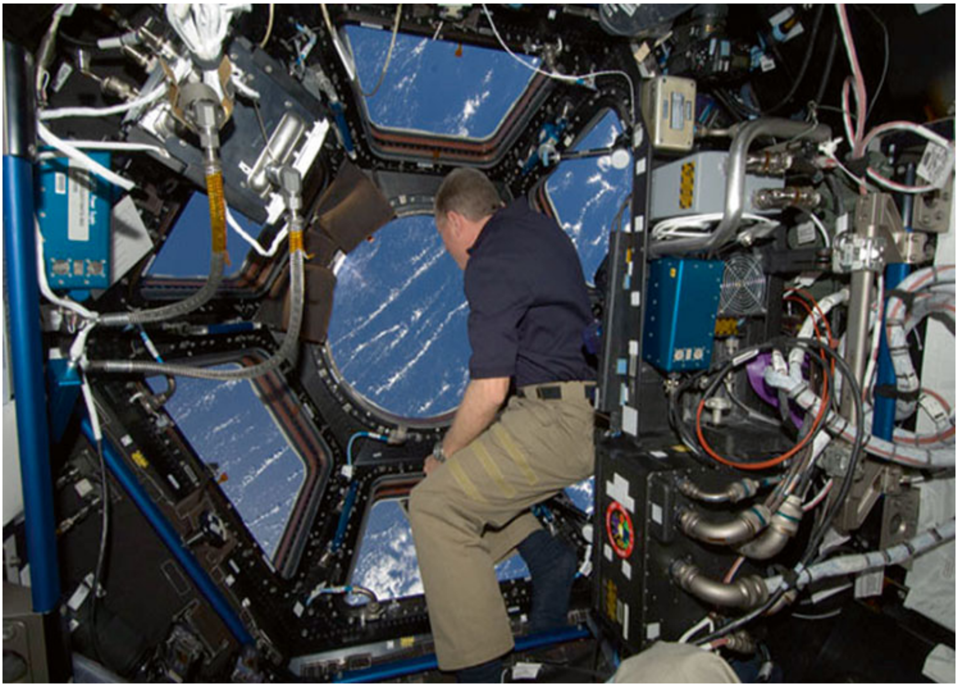
In a space simulation study of three crewmembers who participated in a 135-day isolation in the Mir space station simulator in Moscow, my colleagues and I [21] found that the crew experienced significantly less tension and more expressiveness and self-discovery during their seclusion than during their pre-confinement training period. These results suggested that a more extensive examination of the positive aspects of space travel needed to be done.

In an attempt to do this, my colleague Eva Ihle and some of our team conducted a questionnaire study involving astronauts and cosmonauts who had participated in at least one space mission [22, 23]. Subjects were recruited anonymously from two sources: the Association of Space Explorers (an organization of people who have flown in space) and the NASA astronaut corps at the Johnson Space Center. The final sample consisted of 39 respondents who then completed our Positive Effects of Being in Space questionnaire, a measure specifically developed for this study.

The results showed that every respondent reported at least some positive change as a result of flying in space. The items clustered into eight subscale categories: Perceptions of Earth, Perceptions of Space, New Possibilities, Appreciation of Life, Personal Strength, Changes in Daily Life, Relating to Others, and Spiritual Change. Of these, only one was significantly different from the others and produced a "moderate" level of change in the subjects: Perceptions of Earth. One item from this subscale—"I gained a stronger appreciation of the Earth's beauty"—had the highest mean score: the average rating translated into a "great degree" of change (Fig. 6.3). Perceptions of Earth also was found to be an important factor by Suedfeld et al. [12].

For some of the questionnaire items, elements of attitude change translated into behavioral change after the respondent returned to Earth. For example, three of the items ("I realized how much I treasure the Earth," "I learned to appreciate the fragility of the Earth," and "I gained a stronger appreciation of the Earth's beauty") were significantly associated with the behavioral item "I increased my involvement in environmental causes" after returning. Although the study did not track post-return activities to see whether the subjects indeed followed through on their intended behaviors, these results still suggested a link between attitude change as a result of traveling in space and the subjects' belief that they had acted on these changes after coming home.

Interestingly, ten of the respondents indicated that they were reporting no change in at least one item because no further shift was possible. That is to say, the described experience was already optimal for them, and it could not be enhanced further by being in space. The item most frequently designated as unchangeable was "I became more excited about space exploration," followed by two items from the Spiritual Change subscale: "I have a better understanding of spiritual matters" and "I have a stronger religious faith."



6.3 Astronauts love looking at Earth from space. Here, an astronaut gazes out at our home planet from the cupola of the International Space Station (ISS). NASA/JSC digital image dated November 19, 2011

Although no differences could be found among the respondents along demographic lines, cluster analysis revealed that the subjects segregated into high- and low-change groups. This split may have been due to differences in personality or cognitive styles and needs to be explored further. Understanding the reasons for this split may lead to information that will help crewmembers use more individualized and relevant coping strategies during future long-duration missions, such as an expedition to Mars. For example, our high-change group rated general perceptions of space just behind perceptions of Earth as an important positive change factor during their missions. During the outbound phase of a future Mars expedition, as Earth becomes an insignificant dot in the heavens due to its increasing distance, perhaps the more reactive, high-change crewmembers will find solace from viewing the heavens as a suitable replacement. In our study, the less-reactive subjects rated perceptions of Earth first and appreciation of life second (perceptions of space was fifth). People like these in a Mars crew might benefit more from coping strategies that are inner-focused and life-oriented.

Thus, it might be possible to influence the experiences of the crewmembers in ways that will maximize the chances of their having a positive experience. This will enhance individual well-being, improve crew morale, and likely improve the odds of having a successful mission.

6.3 LINKING EARTH OBSERVATION AND PHOTOGRAPHY

As mentioned at the beginning of this chapter, Cosmonaut Valentin Lebedev found great pleasure in taking photographs of Earth during his 211-day Sayut 7 mission. This linkage between Earth observation and photography was studied by Robinson and her colleagues [24] via a retrospective survey of 19 astronauts and cosmonauts who had flown on eight ISS missions. They found that of over 144,000 photographs taken, 84.5 % were crew-initiated. Even in cases where Crew Earth Observations scientists requested images of Earth, the crewmembers typically took additional photographs for their own enjoyment. Self-initiated images were more likely to occur during free time than during work time. There was no indication that this activity was related to coping with third quarter stress (see Sect. 2.2); in fact, the investigators found no evidence for the third quarter phenomenon in their results. They concluded that Earth photography seemed to be a self-initiated positive activity that increased well-being during long-duration missions and, as such, it should be encouraged during future near-Earth space missions. But as will be discussed in later chapters, other coping strategies will need to be used in missions far away from home, since our planet will become an insignificant dot in the heavens, and the appeal of Earth observation will be lessened.

REFERENCES

1. Connors, M. M., Harrison, A. A., & Atkins, F. R. (1985). *Living aloft: Human requirements for extended spaceflight. NASA SP-483*. Washington, DC: NASA.
2. Kanas, N. (1990). Psychological, psychiatric, and interpersonal aspects of long-duration space missions. *Journal of Spacecraft and Rockets, 27*, 457–463.
3. Lebedev, V. (1988). *Diary of a cosmonaut: 211 days in space*. College Station, TX: Phytoresource Research Information Service.
4. Oberg, J. E. (1981). *Red star in orbit*. New York: Random House.
5. Pogue, W. R. (1985). *How do you go to the bathroom in space?* New York: Tom Doherty Associates.
6. Cordova, M. J., Cunningham, L. L. C., Carlson, C. R., & Andrykowski, M. A. (2001). Post-traumatic growth following breast cancer: A controlled comparison study. *Health Psychology, 20*, 176–185.
7. Wilson, S. R., & Spencer, R. C. (1990). Intense personal experiences: Subjective effects, interpretations, and after-effects. *Journal of Clinical Psychology, 46*, 565–573.
8. Palinkas, L. A. (1991). Group adaptation and individual adjustment in Antarctica: A summary of recent research. In A. A. Harrison, Y. A. Clearwater, & C. P. McKay (Eds.), *From Antarctica to outer space*. New York: Springer.
9. Suedfeld, P. (1998). Homo invictus: The indomitable species. *Canadian Psychology, 38*, 164–173.
10. Suedfeld, P. (2001). Applying positive psychology in the study of extreme environments. *Journal of Human Performance in Extreme Environments, 6*, 21–25.
11. Suedfeld, P. (2005). Invulnerability, coping, salutogenesis, integration: Four phases of space psychology. *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B61–B66.
12. Suedfeld, P., Brcic, J., Johnson, P. J., & Gushin, V. (2012). Personal growth following long-duration spaceflight. *Acta Astronautica, 79*, 118–123.
13. Suedfeld, P., Brcic, J., Johnson, P. J., & Gushin, V. (2015). Coping strategies during and after spaceflight: Data from retired cosmonauts. *Acta Astronautica, 110*, 43–49.
14. Suedfeld, P., & Weiszbeck, T. (2004). The impact of outer space on inner space. *Aviation, Space, and Environmental Medicine, 75*(7 Suppl.), C6–C9.
15. Suedfeld, P., Legkaia, K., & Brcic, J. (2010). Changes in the hierarchy of value references associated with flying in space. *Journal of Personality, 78*, 1–25.

16. Brcic, J., & Della-Rossa, I. (2012). Universal values of Canadian astronauts. *Acta Astronautica, 80*, 46–51.
17. Vinokhodova, A. G., & Gushin, V. I. (2014). Study of values and interpersonal perception in cosmonauts on board the international space station. *Acta Astronautica, 93*, 359–365.
18. Solcova, I. P., Lacev, A., & Solcova, I. (2014). Study of individual and group affective processes in the crew of a simulated mission to Mars: Positive affectivity as a valuable indicator of changes in the crew affectivity. *Acta Astronautica, 100*, 57–67.
19. Kelly, A. D., & Kanas, N. (1992). Crewmember communication in space: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 63*, 721–726.
20. Kelly, A. D., & Kanas, N. (1993). Communication between space crews and ground personnel: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 64*, 779–800.
21. Kanas, N., Weiss, D. S., & Marmar, C. R. (1996). Crewmember interactions during a Mir space station simulation. *Aviation, Space, and Environmental Medicine, 67*, 969–975.
22. Ritsher, J. B., Ihle, E. C., & Kanas, N. (2005). Positive psychological effects of space missions. *Acta Astronautica, 57*, 630–633.
23. Ihle, E. C., Ritsher, J. B., & Kanas, N. (2006). Positive psychological outcomes of spaceflight: An empirical study. *Aviation, Space, and Environmental Medicine, 77*, 93–101.
24. Robinson, J. A., Slack, K. J., Olson, V., Trenchard, M. H., Wilis, K. J., Baskin, P. J., et al. (2013). Patterns in crew-initiated photography of Earth from the ISS: Is Earth observation a salutogenic experience? In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin, Germany: Springer.

7

Space Tourism

Space tourism refers to space travel that primarily is made for recreational or leisure-time purposes and is organized through private means [1, 2]. However, some private space travelers have objected to being called "space tourists," since they engaged in space-related business or research activities during their mission. In fact, NASA, the Russian Federal Space Agency, and the US Federal Aviation Administration (FAA) prefer the term "spaceflight participant" to distinguish such people from career astronauts. This term has also been used legally to refer to people not involved in the general operation of a spacecraft [3].

At this point in time, it is useful to think about space tourism in two ways: suborbital missions and orbital missions. Although to date, government carriers have been used to launch some suborbital and all orbital spaceflight participants aloft, in the near future it is likely that private companies will take over the business entirely, both in terms of carriers and in terms of orbital destinations (such as an orbiting hotel or resort). Looking far into the future, the destinations may include the Moon or distant bodies in our Solar System, such as Mars of the moons of Jupiter.

7.1 THE MARKET FOR SPACE TOURISM

What are the interest and demand for space tourism? In October 2002, a survey was published by the Futron Corporation, a company that specializes in forecasting space-related markets [4]. The respondents were millionaires who were able and willing to participate in either suborbital fights (72 % male, with an average age of 55) or orbital flights (89 % male, with an average age of 53). Sixty-three percent rated the chance to view Earth from space as the most attractive feature of their participation. Over half of the respondents said that their desire to fly suborbitally was not affected by the choice of vehicle (government or private) or for orbital missions, physical discomforts experienced. Based on the survey, Futron projected that the suborbital market could reach over 15,000 passengers by 2021, and the orbital market could reach 60 passengers per year. The total annual revenue of these activities was projected to be over US$1 billion.

Another survey was conducted of people biased toward adventurous activities (e.g., skydiving, mountain climbing) [5]. Unlike the Futron survey, only 14 % were

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_7

millionaires, and the respondents generally were younger (94 % under the age of 60). Ninety-one percent were male. The survey revealed that in this group, price was an issue. Only 7 % said that they would undertake a suborbital flight at a price of US$100,000 or above, but this number increased to 36 % if the price dropped to under US$50,000. Only 4 % would pay US$10–20 million for an orbital flight, whereas about a third would take such a flight for US$5 million or below. Seventy percent said they would be happy with an orbital mission that lasted 2 weeks or less, and 88 % indicated an interest in taking a spacewalk. In terms of training, 59 % were willing to spend up to 2 weeks for a suborbital flight, which is comfortably within the range anticipated by most commercial companies. However, 59 % also said that the maximum acceptable time they would spend training for an orbital mission was three months, which is less than half of the time that was spent by spaceflight participants who previously have flown to the International Space Station (ISS) (see below).

Eric Seedhouse [2] reviewed the results of a market survey conducted by the Tauri Group in November 2011 to forecast demand to travel on suborbital reusable launch vehicles (RLVs). The surveyed group included potential users and providers, researchers, and high-net-worth individuals. The results suggested that there are enough high-net-worth individuals worldwide (around 8,000) willing and able to pay an average cost of around US$123,000 for a suborbital flight. Over the next 10 years, growth in this population, plus the addition of less affluent enthusiasts, should bring the number to over 10,000 people likely to have flown on a suborbital mission.

So, despite the high cost, there appear to be plenty of people who are willing to pay to go into space, see Earth from afar, and experience microgravity (Fig. 7.1). As of March 2014, Virgin Galactic had sold some 700 tickets at a price of around US$200,000 each and accepted more than US$80 million in deposits from individuals wanting to go on a suborbital mission. XCOR is selling tickets on their Lynx for under US$100,000 each [2]. In addition, Virgin Galactic and NASA have identified 12 innovative research payloads that will fly into space on board the Virgin Galactic SpaceShipTwo from the new Spaceport America facility in Las Cruces, New Mexico [6]. The potential for privately supported space missions seems very strong. Seedhouse [1] predicts that as the next generation of space vehicles are developed, the price for a suborbital mission will drop to below US$50,000, eventually reaching the US$10,000 range.

The fee for orbital missions likely will be much higher. Several private citizens who have already flown to the ISS were willing and able to pay the US$20–40 million price. This likely will decrease in the future, but how much is hard to predict at the present time. Figures as low as US$5–8 million are projected, making it likely that in the foreseeable future, only multimillionaires will be able to afford an orbital trip [1]. But by one estimate, if the price could be dropped to a mere US$500,000, thousands of customers could be lured into making orbital tourist trips [2]. However, many potential candidates may be discouraged by the stricter training requirements, especially since most of them have busy lives on Earth and would not be able to spend more than 1–2 months in spaceflight training. Also, based on the Space Shuttle experience, the chances of a fatal accident during an orbital mission may approach 4–5 %, and some people will consider this to be unacceptably high.

Along these lines, the space-tourism industry recently suffered two setbacks. On October 28, 2014, an Orbital Sciences Corporation unmanned Antares rocket blew up just

7.1 One of the joys of being in space is experiencing microgravity. This Space Shuttle crew is having this experience during training in the KC-135 aircraft, which flies giant parabolic arcs in the sky that counter gravity. However, the experience lasts less than a minute at a time. NASA/JSC digital image dated December 17, 1984

moments after lift-off. It was carrying a Cygnus capsule loaded with science experiments and equipment and prepackaged meals for the ISS crewmembers. Although no lives were lost, this accident raised some doubt about the ability of private companies to send supplies into space. More tragically, on October 31, 2014, a Virgin Galactic SpaceShipTwo test vehicle broke up in flight, causing the death of the co-pilot and injuries to the pilot (who miraculously managed to parachute down to Earth). These two events are bound to slow the momentum of the space-tourism industry and raise concerns about safety and reliability.

7.2 LEGAL AND ENVIRONMENTAL ISSUES

At the present time, many legal aspects of commercial space travel are covered by applicable international space laws (established by several UN treaties and resolutions) and national space legislation in the country legally responsible for the launch of the mission.

For example, in the US, the FAA Office of Commercial Space Transportation has been tasked with approving and regulating commercial rocket launches from its territory. Air law also would apply to parts of some flights originating on the ground. But there is confusion at the level of international law, and it has been argued that a sensible integrative approach needs to be developed that borrows from current space law, air law, and high-risk adventure tourism law [7]. Failure to do so entails significant safety risks [8].

Confusion also exists in terms of liability for harm to spaceflight participants [1–3]. For example, the US has established perhaps the most sophisticated national space legislation. Under this legislation, spaceflight participants are required to sign informed consent acknowledging the potential dangers of their mission. Because they are voluntarily subjecting themselves to these risks, space vehicle operators are not prevented from including a waiver of liability as part of the agreement to fly, except in cases of gross negligence [3]. This means that they may not be liable for an accident or death that occurs to a spaceflight participant during the mission. Furthermore, the operators may require that an applicant obtain expensive life and liability insurance, such as has happened during previous Russian orbital space missions involving civilians [3]. More work needs to be done in the liability and insurance areas as commercial space travel becomes more of a common occurrence [9].

The environmental impact of space tourism also needs to be clarified. In a 2010 computer simulation study, concerns were raised that the expanding commercial space industry could release tons of black carbon (i.e., soot) that would persist in the stratosphere. This could alter global atmospheric circulation and the distribution of ozone. One computer model resulted in an increase in temperature at the poles of up to 1 °C and a reduction of polar sea ice by 5–15 % [10]. The impact of space tourism on climate change needs to be studied as it continues to evolve and grow, especially if launch vehicles are used that have the more economical hybrid engines that ignite synthetic hydrocarbons with nitrous oxide instead of the more traditional engines that use kerosene and oxygen and emit less black carbon [10].

7.3 SUBORBITAL MISSIONS

7.3.1 Early History

The history of private suborbital flight into space is fairly recent [1–3, 11]. Most people consider space to begin at an altitude of 100 km (62 miles). On June 21, 2004, this altitude was exceeded by Michael Melvill in the privately built SpaceShipOne, designed by Burt Rutan of Scaled Composites and funded largely by Microsoft co-founder Paul Allen. Melvill repeated this feat on September 29, 2004. Shortly thereafter, this vehicle was awarded the Ansari X-Prize of US$10 million by going into space twice within two weeks and carrying one civilian pilot and the equivalent weight of two additional occupants. The pilot of the second flight was Brian Binnie, and his mission occurred on October 4, within the 2-week window required for the prize [2, 3]. Each time, this space ship was carried aloft on the airplane WhiteKnightOne, which flew from the Mojave Airport and dropped its precious cargo at an altitude of 14,000 m, where its rocket motor was ignited and it flew up into space.

Shortly thereafter, Sir Richard Branson of Virgin Atlantic Airways announced that he would be setting up a new company called Virgin Galactic. This would contract with Allen and Rutan to build a fleet of new six-passenger spaceliners to be named SpaceShipTwo that would fly into space. The new carrier aircraft would be the WhiteKnightTwo. The tourist fee would be US$200,000, for which the passengers would experience several minutes of weightlessness during their 2-h suborbital flight. This stimulated the suborbital commercial space business, with several companies entering into the field [1–3, 11].

7.3.2 Vehicles and Habitats

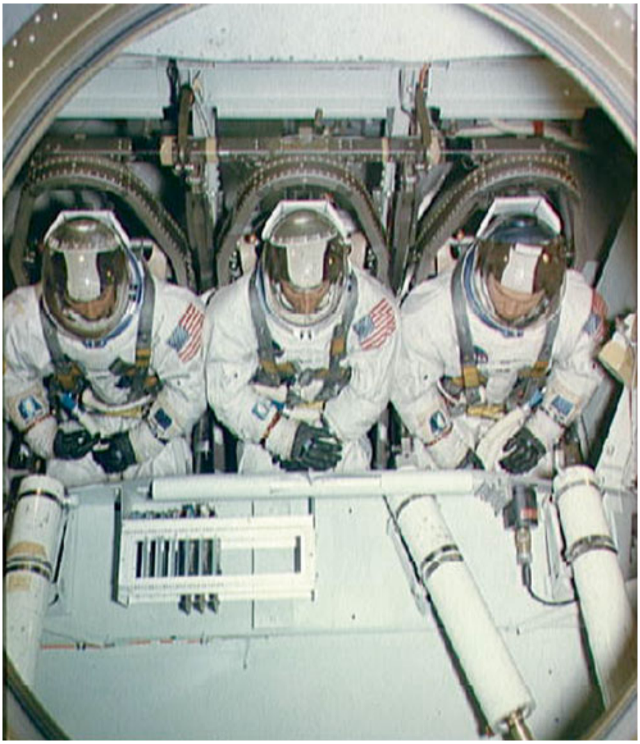
The private aerospace industry is still growing and developing, and many vehicles still are in the planning stages. In general, three types of vehicles have been proposed for suborbital missions: those that ignite in the air after being carried aloft and released by a plane (e.g., SpaceShipTwo) or a huge balloon (e.g., WildFire); those that take off horizontally from a runway (HTO), such as the Rocketplane, XCOR's Xerus, the Lynx spacecraft, and the European EADS Astrium; and those that are launched from the ground in a vertical take-off (VTO) mode, either directly using their own rocket power (such as the New Shephard and Armadillo vehicles) or piggybacked atop a more conventional rocket (such as the Sierra Nevada Corporation (SNC) Dream Chaser and the Starchaser/Thunderstar vehicle) [1, 2]. Both single and multi-engine designs are proposed that use traditional liquid or solid propellants or hybrid technology. A promising new development would utilize scramjet technology [3]. Some suborbital vehicles include emergency-ejection systems, and some require their passengers to wear pressure suits. Traditional private launch locations have included the Mohave and Oklahoma Spaceports and Spaceport America, which was built in 2010 in Las Cruses, New Mexico. Other space ports are being planned outside of the US, including the Caribbean and Sweden [2].

7.3.3 Training Issues

Training programs being proposed for suborbital missions will last from 3 to 14 days, depending on such optional issues as learning to operate an emergency-ejection system or a requirement to wear a pressure suit. Seedhouse [1] has outlined a detailed generic 21-h, 2-day training program for spaceflight participants on suborbital missions. Recently, he has stated that this training can be simplified to 3 or 4 days, and he has included many of the training issues in a Suborbital Ground School Manual [2]. His program includes a number of medical and operational issues, including vehicle orientation, spaceflight theory, survival training, high-altitude and G-tolerance indoctrination, and experience in a hypobaric chamber and a centrifuge (Fig. 7.2). Participants also undergo brief episodes of microgravity during a series of airplane parabolic flights. Survival and launch escape-system training also is part of the package.

7.3.4 Medical and Psychological Issues

Participants also must be prepared for the medical and psychological challenges of a suborbital flight [1–3, 12]. Spaceflight produces a number of medically relevant stressors, such as high acceleration, changes in barometric pressure, microgravity, ionizing and



7.2 The Apollo 8 crew inside a centrifuge gondola during training prior to their mission. Future spaceflight participants also will need to undergo centrifuge training in preparation for the increased G-loads during the launch of their mission. NASA/JSC digital image dated November 1, 1968

non-ionizing radiation, increased cabin noise and vibration, temperature and humidity fluctuations, cabin air contaminants, and behavioral issues (e.g., isolation and confinement, risk of injury or death, lack of privacy, stressful crew interactions). Many spaceflight participants may not be as healthy or young as a typical astronaut and may have ongoing health problems that are being treated. Therefore, it is essential that they receive a complete pre-flight medical history and examination, which includes relevant laboratory and drug tests and a psychiatric and mental status evaluation.

At the same time, paying customers may demand certain accommodations that are more typical of flying first class in a commercial airplane than in a space vehicle (e.g., gourmet food, alcoholic beverages). Consequently, some of the strict criteria typical of government-sponsored programs that were developed for career astronauts may need to be relaxed. Realistic guidelines should be created that allow spaceflight participants their preferences, while at the same time not compromising their safety as well as the safety of the crew and other paying customers [3].

In 2006, medical screening guidelines were published by the FAA to assist operators of commercial spaceflights in assessing prospective passengers [13]. This document defines

two categories of passengers (suborbital and orbital), describes a number of medical risks associated with acceleration, and lists a number of possible medical contraindications for participation in such flights (e.g., active cancer, severe acute infection, previous overexposure to radiation, current pregnancy). The appendices list a number of items to be checked in the medical history, physical examination, and laboratory testing of prospective spaceflight participants.

The guidelines also state that people with medical contraindications may still be certified for spaceflight on a case-by-case basis pending further evaluation and treatment. In some cases, it might be possible to permit special medical accommodations for prospective passengers with disabilities. For example, Professor Stephen Hawking, who suffers significant mobility impairment from advanced amyotrophic lateral sclerosis, was able to participate in a zero-gravity flight by being accompanied by his own medical team and by being monitored by non-invasive biomedical equipment during the mission [3].

In terms of psychological contraindications, the guidelines include: "Any psychiatric, psychological, mental, or behavioral disorder that would cause an individual to become a potential hazard to him/herself or to others" ([8], p. 3). Specific problem areas would include a history of acute psychosis or schizophrenia, bipolar (manic–depressive) disorder, severe personality disorder, or a recent history of substance abuse or dependency [1]. Also, many of the stressors of space, such as the tight quarters and the increased cabin noise and vibration, can cause claustrophobia, anxiety, and disturbances in sleep, so vulnerability to such factors should be assessed prior to launch. However, since most suborbital missions will last only a few hours, many psychological and interpersonal stressors that could produce behavioral problems during longer orbital missions will not play a significant role in these briefer flights.

7.4 ORBITAL MISSIONS

7.4.1 Early History

The Soviet/Russian space program has a long history of ferrying up "guest" astronauts to their space stations as part of their Intercosmos Program. Most were trained as cosmonauts and were selected by allied countries. They also sent up a privately funded Japanese man and a British woman to their Mir space station in the early 1990s [2]. NASA ferried non-astronaut civilians who received less training than their astronauts into space on their Space Shuttle. These included a businessman, a US Senator, and a US Congressman (Fig. 7.3). The intent was to increase civilian involvement, but the program was halted in 1986 with the death of teacher Christa McAuliffe and her fellow crewmembers in the *Challenger* disaster.

Orbital space tourism officially began in earnest through the brokering activities of a company called Space Adventures [9]. As a result of a joint commercial venture between them, the Russian Federal Space Agency, and Rocket Space Corporation Energia, seven private spaceflight participants paid US$20–40 million each to make eight spaceflights to the ISS on board Russian Soyuz spacecraft. They are: Dennis Tito (American, 2001); Mark Shuttleworth (South African/British, 2002); Gregory Olsen (American, 2005);

7.3 US Representative Bill Nelson of Florida undergoing medical tests at Johnson Space Center before his Space Shuttle flight in 1985. Future private spaceflight participants will also need to undergo pre-launch physical examination and testing, as discussed below. NASA/JSC digital image dated September 24, 1985

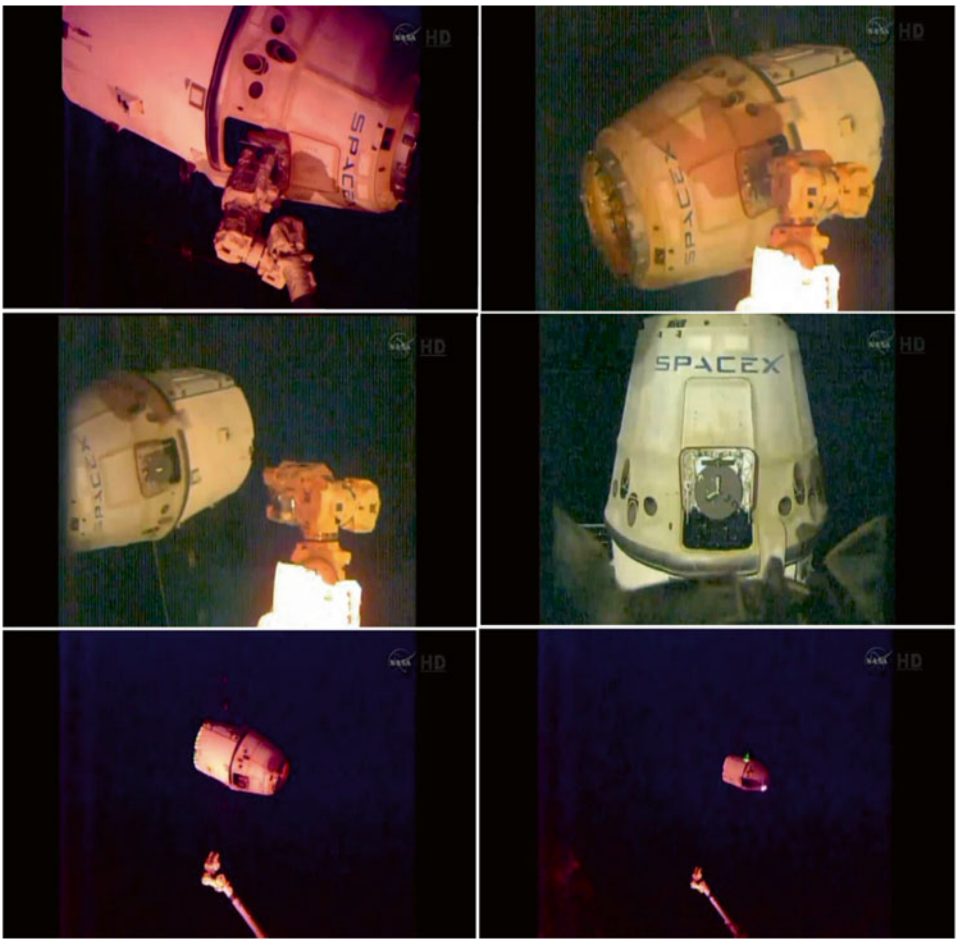
Anousheh Ansari (American/Iranian, 2006); Charles Simonyi (American/Hungarian, 2007 and 2009); Richard Garriott (American/British, 2008); and Guy Laliberte (Canadian, 2009) [2]. These spaceflight participants spent 8–15 days in space, and several conducted scientific experiments and performed routine ISS duties. The program was halted in 2010 when the ISS crew size increased and the extra Soyuz seat was sold back to astronauts, but the Russians plan to resume the program in the future. Space Adventures plans to launch singer Sarah Brightman into orbit in late 2015 on a Soyuz spacecraft, and they have entered into an agreement with Boeing to market seats on their new CST-100 spacecraft starting in 2017 [14, 15].

7.4.2 Vehicles and Habitats

Plans are being made to have non-ISS habitats in space that can receive orbital spaceflight participants. On July 12, 2006, Robert Bigelow, founder of Bigelow Aerospace, launched the first of his orbiting habitats, which was named Genesis I. He acquired the design for this inflatable space structure from NASA's abandoned Transhab program. The cargo included live cockroaches and jumping beans [2]. This was followed a year later by a much larger Genesis II, carrying cockroaches and scorpions. Plans currently are being made to launch the B330, a 330-cubic-meter habitat that would be able to accommodate up to six people [16]. Although in 2004 Bigelow offered a US$50 million prize for any company developing a reusable spacecraft that could ferry passengers up to its habitats, the prize has since

expired for lack of applicants. There also are Russian options to build a permanent habitat in space and to offer trips to the Moon on refitted Russian spacecraft [2].

A number of companies are planning to use vertically launched non-reusable rockets to ferry people up into space. Elon Musk's Space Exploration Technologies (SpaceX) has developed a rocket family named Falcon, and these rockets have successfully launched commercial satellites into orbit. The plan is for the Falcon 9 rocket to ferry up a capsule named Dragon that will be capable of transporting up to seven people to an orbiting space station. An unmanned version of Dragon successfully docked with the ISS on October 25, 2014, bringing scientific and other cargo back to Earth [17] (Fig. 7.4). The company hopes



7.4 A series of images showing SpaceX's unmanned Dragon spacecraft leaving the International Space Station (ISS) for Earth on October 25, 2014. It contains science samples and other cargo from the ISS. The plan is for a version of this spacecraft to ferry spaceflight participants to and from orbiting space stations. NASA Image, Release 14-295, October 25, 2014

to develop a reusable version of this rocket in the future. As mentioned in the previous section, Boeing is developing their manned CST-100 capsule, which would be launched aboard an Atlas V rocket and be capable of carrying up to five people into space. Recently, both SpaceX and Boeing were awarded contracts by NASA to transport astronauts to the ISS, perhaps as early as 2017 [18]. These companies are planning to include non-astronaut passengers, and they are working with Bigelow Aerospace to fly to its habitats as well. Other American companies planning to launch people into orbit include Rocketplane Kistler Aerospace Corporation and its two-stage K-1 spacecraft; SNC and its Dream Chaser manned vehicle; and Transformational Space Corporation and its Crew Transfer Vehicle (CXV), which would be carried into the sky and dropped by an airplane [1, 2].

7.4.3 Training Issues

To date, training programs for spaceflight participants undergoing orbital missions have been similar to programs undergone by astronaut mission specialists. However, in order to support an active orbital tourist industry, these need to be simplified and shortened from 6 months to 1–2 months. Seedhouse [1] has outlined a detailed generic 5-week program that covers many of the issues mentioned above for suborbital flight (see Sect. 7.3.3), but in greater detail. This is because of the increased medical/physiological and psychological demands brought about by the duration of the missions, the stresses of microgravity (including space motion sickness), and the prolonged isolation and confinement. Much of this program has been included in an Orbital Ground School Manual [2].

7.4.4 Medical and Psychological Issues

Many of the medical and psychological issues mentioned above for suborbital flight apply to orbital missions as well. In the more distant future, orbiting space habitats likely will be roomier and will have some sort of artificial gravity (e.g., they will rotate around a center so as to produce a centrifugal force of 1 *g* in the periphery where people live). But in the early space-tourism days, the habitat will be the launched capsule itself or some sort of space station or Bigelow structure where microgravity is present. The physiological stressor of microgravity can challenge the body, and being cooped up with people in a cramped isolated environment can challenge the psyche. Countermeasures for dealing with these stressors need to be available and applied in order for the private market to develop.

Spaceflight participant orbital missions to date have lasted 8–15 days—about the time that was typical for Space Shuttle missions. In a study of 607 astronauts and payload specialists involved in 106 Shuttle missions, 98.1 % of the men and 94.2 % of the women reported an average of one medical event or symptom every 2.5 days of flight [19]. The locations of these problems are shown in Table 7.1. There were 194 events due to injury, and 14 fatalities [3]. So even in trained astronauts, the incidence of medical problems that can occur in space is fairly high. These incidences likely would be greater for less physically fit spaceflight participants on longer missions. This would include psychiatric problems, especially in people with histories of personality disorder, adjustment and psychosomatic reactions, anxiety disorders and phobias, severe depression, acute psychosis or schizophrenia, bipolar disorder, suicidality, and substance abuse [3].

Table 7.1 In-flight Space Shuttle medical events

Medical event or system involved	%
Space adaptation syndrome (space motion sickness)	39.6
Episodic insomnia and fatigue	36.0
Nervous system and sensory organs	16.7
Digestive system	9.2
Injuries and trauma	8.8
Musculoskeletal system and connective tissue	8.2
Skin and subcutaneous tissue	8.0
Respiratory system	4.5
Behavioral signs and symptoms	1.8
Genitourinary system	1.5
Infectious diseases	1.3
Circulatory system	0.3
Endocrine, nutritional, metabolic, and immunity disorders	0.1

Adapted from [19]

Most people able to afford going on a future orbital mission likely will be older and perhaps not as healthy as a typical astronaut or mission specialist. In December 2007, the ISS medical community published an extensive list of medical standards and evaluation requirements for spaceflight participants undergoing short-term visits to the ISS of less than 30 days [20]. Although less stringent than the requirements for professional astronauts, they still are very strict, and they may exclude many potential applicants from flying who have a medical or psychiatric problem.

People with such conditions need to be evaluated on a case-by-case basis for travel into orbit, and it is possible for people to undertake such a mission with proper precautions. Jennings and his colleagues [21] presented a case study of a 57-year-old man with several medical conditions involving his heart and lungs. By undergoing careful evaluations in space analog conditions, and being treated prophylactically for his conditions, he finally was certified for flight and successfully completed a 10-day mission to the ISS. More work needs to be done in the area of waiving certain medical conditions with proper preparation and treatment, especially as the number of people who are willing and are financially able to be spaceflight participants increases in the future.

7.5 LUNAR AND SOLAR SYSTEM MISSIONS

Where do well-heeled space enthusiasts go to enjoy a more extended trip into space? Well, they can perhaps visit a large orbiting resort and either relax by observing the beauty of Earth or engage in space-diving while being decked out in the latest-fashion spacesuit built to withstand the thermal stress of re-entry and containing parachutes for safe landing [1]. If they are tired of the orbital experience, perhaps they can visit a habitat on the Moon, playing golf in the 1/6th Earth gravity, or simply jog-hopping on the surface.

There is great incentive for a commercial space venture to the Moon. Google has offered a Lunar X-Prize of US$20 million to the first privately funded team to fly and land

a spacecraft on the Moon, travel 500 m across its surface, and transmit high-definition footage back to Earth. With some 33 teams in the competition, it is hoped that a winner will emerge and that the prize will lead to the same sort of bump in commercial space activities to the Moon that the Ansari X-Prize provided for suborbital missions [22, 23].

Plans for lunar tourism already are underway. Space Adventures is offering advanced booking for a circumlunar mission, and Golden Spike aims to begin flying roundtrip missions that will land and return people from the lunar surface by 2020. The cost will be a mere US$1.5 billion per mission [23, 24].

Visits to the planets in our Solar System also are in the works, including orbiting habitats around Venus that will allow shuttle excursions into its atmosphere, or land-based facilities on Mars that will allow private payers the opportunity to see the giant volcanoes and deep chasms on its surface. Some of the outer planets also might be vacation destination sites, such as the moons of Jupiter or Saturn. Europa especially might be attractive, with its icy surface allowing for ice skating or skiing, and its subsurface water possibly teaming with life to be observed by the enthusiastic scuba-diver [1]. Although such trips are way into the future, Seedhouse [2] has outlined a number of possible day-by-day itineraries for tourist visits to the Moon, Mars, and Europa.

Missions beyond Earth orbit present hazards for spaceflight participants. Four kinds of danger exist: collisions with micrometeoroids and space debris; bodily damage from solar flares and other sources of radiation beyond the protective shield of Earth's Van Allen belts; bone loss, muscle atrophy, and other physiological sequelae from microgravity; and psychological and interpersonal problems resulting from people living in dangerous and confined habitats for long periods of time [25].

One way of avoiding some of these dangers is to provide virtual space tourism. Genta [23] has discussed this issue with reference to the Moon. In this scenario, a rover with video equipment roams the lunar surface and sends images back to Earth that are used to create a virtual reality scenario. The experience can be made more real by providing a way for the "tourist" to control the rover and thus feel like he or she is actually traveling on the Moon. Such an activity is safe and will be much less expensive than actually sending a person into space. It may even be applicable for experiences beyond the Moon, but then one runs into time delays due to the vast distances involved. For example, traveling at the speed of light, a message from Earth can take 20 min or longer to reach a rover on Mars, and a similar amount of time to return the response back to the sender. This certainly would interfere with the sense of being on the Red Planet and operating one's own vehicle in real time. Nevertheless, virtual space tourism might appeal to some people and interest them to the point where they would want to participate directly in further space activities.

Whether real or virtual, space tourism as an enterprise has a bright future, provided that, like an expensive sea cruise, people have the time and money to undertake it. As more and more wealthy people participate in space-related activities, an economy of scale will occur that leads to lower prices. As people with less money become involved, corporate competition likely will adjust to their needs by providing a range of activities to accommodate different budgets and priorities, from simple flights to long-term stays in orbiting or surface resorts. The sky will be the limit!

REFERENCES

1. Seedhouse, E. (2008). *Tourists in space: A practical guide*. Chichester, England: Springer/Praxis.
2. Seedhouse, E. (2014). *Tourists in space: A practical guide* (2nd ed.). Chichester, England: Springer/Praxis.
3. Antunano, M., Hobe, S., & Gerzer, R. (2009). *Medical safety and liability issues for short-duration commercial orbital space flights*. Paris, France: International Academy of Astronautics.
4. Beard, S. S., & Starzyk, J. (2002). *Space tourism market study: Orbital travel and destinations with suborbital space travel*. Bethesda, MD: Futron Corporation. www.spaceportassociates.com.
5. Webber, D., & Reifert, J. (2006). *"Filling in some gaps": Executive summary of the Adventurers' survey of public space travel*. Bethesda, MD: Spaceport Associates. www.spaceportassociates.com.
6. NASA and Virgin Galactic select payloads for first space research flight onboard SpaceShipTwo. www.virgingalactic.com/news/item/nasa-and-virgin-galactic-select-payloads-for-first-space-research-flight-onboard-spaceshiptwo/
7. Von der Dunk, F. G. (2013). The integrated approach: Regulating private human spaceflight as space activity, aircraft operation, and high-risk adventure tourism. *Acta Astronautica, 92*, 199–208.
8. Beamer-Downie, D. (2013). Considering the unthinkable: A review and discussion of current international law and suggestions regarding how we deal with a catastrophic incident in space. *Acta Astronautica, 92*, 255–262.
9. Van Oijhuizen Galhego Rosa, A. C. (2013). Aviation or space policy: New challenges for the insurance sector to private human access to space. *Acta Astronautica, 92*, 235–242.
10. Mann, A. (2010). Space tourism to accelerate climate change. *Nature.* Retrieved October 22, from www.nature.com/news/2010/101022/full/news.2010.558.html
11. Webber, D. (2013). Space tourism: Its history, future and importance. *Acta Astronautica, 92*, 138–143.
12. Kluge, G., Stern, C., Trammer, M., Chaudhuri, I., Tuschy, P., & Gerzer, R. (2013). Commercial suborbital space tourism: Proposal on passenger's medical selection. *Acta Astronautica, 92*, 187–192.
13. Artunano, M. J., Baisden, D. L., Davis, J., Hastings, J. D., Jennings, R., et al. (2006). *Guidance for medical screening of commercial aerospace passengers. DOT/FAA/AM-06/1*. Washington, DC: Federal Aviation Administration.
14. Space Adventures website. Retrieved from www.spaceadventures.com/index.cfm?fuseaction=orbital.Orbital
15. Spaceflight Now News website. Retrieved from http://spaceflightnow.com/news/n1009/15boeingtourism/
16. Bigelow Aerospace website. Retrieved from www.bigelowaerospace.com/b330
17. Critical NASA Science Returns to Earth aboard SpaceX Dragon Spacecraft (2014). NASA Press Release 14-295. Retrieved October 25, from www.nasa.gov/mission_pages/station/structure/launch/index.html
18. Chang, K. (2014). 2 companies will take Americans to space station. *New York Times.* Retrieved September 16, from www.nytimes.com/2014/09/17/science/space/boeing-and-spacex-win-contracts-to-carry-americans-to-space-station.html?_r=0
19. Johnston, S.L., III (2013). Space medicine applications for terrestrial wellness. NASA Johnson Space Center. Retrieved from www.dsls.usra.edu/education/grandrounds/archive/2013/20130226/20130226.pdf
20. Bogomolov, V. V., Castrucci, F., Comtois, J.-M., Damann, V., Davis, J. R., et al. (2007). International space station medical standards and certification for spaceflight participants. *Aviation, Space, and Environmental Medicine, 78*, 1162–1169.
21. Jennings, R. T., Murphy, D. M. F., Ware, D. L., Aunon, S. M., Moon, R. E., et al. (2006). Medical qualification of a commercial spaceflight participant: Not your average astronaut. *Aviation, Space, and Environmental Medicine, 77*, 475–484.
22. Bowler, S. (2014). The new race to the Moon. *Astronomy and Geophysics, 55*, 5.15–5.17.
23. Genta, G. (2014). Private space exploration: A new way for starting a spacefaring society? *Acta Astronautica, 104*, 480–486.
24. Golden Spike website. Retrieved from http://goldenspikecompany.com
25. Kanas, N., & Manzey, D. (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA: Microcosm Press.

8

Countermeasures for Space Travel

Given the various stressors of on-orbit spaceflight that we have discussed previously, the question arises as to what we can do about them. Certainly, appropriate crewmember selection is one way of preparing for the vicissitudes of a space mission, and this was considered in Sect. 2.1. In addition, relevant training before launch is critical to help the crewmembers identify problematic areas and teach them ways of dealing with them. Once underway, in-flight monitoring and support are important to identify problems and initiate strategies for coping, such as encouraging positive crew interactions and providing opportunities for crewmembers to pursue personal interests and communicate with family and friends on Earth. Holidays and other celebrations also can improve morale (Fig. 8.1). Finally, the post-mission period may be difficult for both space travelers and their families to deal with, especially for high-visibility missions accompanied by fame and glory or where the separation from loved ones on Earth is extreme. Let's take a closer look at countermeasures for dealing with psychosocial problems in space in terms of pre-launch training, in-flight monitoring and support, and post-mission readaptation.

8.1 PRE-LAUNCH TRAINING

Pre-launch psychological training aims at preparing crewmembers for the demands of their mission. It complements crew selection and focuses on the well-being of the crewmembers and their ability to perform the tasks that will be demanded of them in order to accomplish the mission goals. Most training activities center on the crewmembers themselves, but important training activities also involve Mission Control personnel. Although many training activities are conducted with each group separately, in some cases both the crew and Mission Control staff should be trained together. This allows each group to understand the problems of the other more clearly and enhances their ability to communicate openly during the mission.

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_8

8.1 Parties and celebrations of holidays can boost morale and bond astronauts together. Here, American, Russian, and European crewmembers celebrate Christmas on board the International Space Station (ISS). NASA/JSC digital image dated December 25, 2011

8.1.1 Training Topics

Based on our Mir and International Space Station (ISS) research, my colleagues and I have identified a number of psychological, interpersonal, and cultural training areas for future space missions. Topical areas include: coping with isolated and confined environments (ICEs), the relationship between crewmembers and Mission Control personnel, the possible impact of displacement on this relationship, the appropriate use of leadership roles, and the importance of national and organizational norms on international activities [1, 2]. Not only familiarity but also mastery of the common language(s) used in the mission should be a training goal for crews and key Mission Control personnel. This includes visits to the countries of origin of the crewmembers in order to gain a proper linguistic and cultural perspective.

Kring [3] has identified several areas related to cross-cultural training, especially those pertaining to the national origin of the participants. These include communication; cognition and decision making; technology interfacing; interpersonal interactions; work, management, and leadership style; food preparation and meals; religion and holidays; recreation; habitat aesthetics; and personal hygiene and clothing (Fig. 8.2). Based on his analysis, Kring has proposed a multicultural training approach for both crewmembers and Mission Control personnel that involves six steps: (i) providing all trainees with a brief overview of each person's cultural background, (ii) describing the areas mentioned above in terms of their importance for the mission, (iii) allowing the trainees to record their own mission preferences with regard to the these areas, (iv) facilitating a group discussion

8.2 Keeping up appearances is evidence of good morale during a space mission. Here, an American astronaut trims the hair of his Japanese crewmate during an International Space Station (ISS) mission. NASA/JSC digital image dated August 27, 2011

regarding the rationale for these preferences, (v) collectively agreeing on behaviors acceptable to everyone during the mission, and (vi) recording a final set of guidelines.

Astronauts sometimes perceive a lack of empathy and understanding from ground personnel for the difficulties they face during the mission [1, 2, 4]. Sometimes, this is a by-product of interpersonal issues among the crewmembers themselves, who may experience tension and problems with their colleagues in space but cannot resolve them openly. As a result, they may displace their feelings to people in the "out-group" of Mission Control who are monitoring their behavior (see Sect. 4.8). This can interfere with the crew–ground relationship and lead to in-group/out-group communication difficulties. Dealing with intra-crew tension and the crew–ground relationship are important areas for pre-launch training.

The effective psychological training of astronauts (and Mission Control personnel) requires that mission-relevant behavioral competencies (and associated knowledge, skills, and attitudes) be identified and used in the training curriculum. Ideally, these competencies should be based on both theoretical analyses as well as relevant experiences and lessons learned from actual space missions. Examples of competency categories used in training people for ISS missions include self-care and management, teamwork and group living, leadership, cross-cultural issues, communication, conflict management, situational awareness, and decision making and problem solving [5, 6].

8.1.2 Kinds of Training

Training should utilize both didactic and experiential techniques. Three complementary approaches of psychological training can be distinguished: briefings, lectures, and workshops; field exercises; and crew-oriented sensitivity and team-building training.

Briefings, lectures, and workshops are the most common and easy to implement. Experience with military pilots suggests that operationally oriented astronauts and Mission Control personnel prefer briefings that are problem-focused and oriented toward direct action [7]. Such methods lend themselves well to linkages with the competence-based approaches mentioned above. For example, specific briefings and workshops can make astronauts aware of their own responsibilities for maintaining mood and performance efficiency in space. These methods include hands-on training with actual space equipment (Fig. 8.3). In addition, briefings and lectures can be used to enhance general awareness of cultural differences and provide relevant knowledge concerning national, organizational, and professional cultures. Most of the psychological training for crewmembers has relied on this kind of didactic teaching. The approaches typically use live seminars or workshops that involve a mixture of briefings, lectures, and round-table discussions. However, computer-based training is being utilized more and more, which includes taped lectures by experts, demonstrations provided by audio-video vignettes, and interactive approaches for feedback and testing. This approach also can be used as a training or refresher tool later on during the mission.

8.3 Space Shuttle astronauts examine the contents of a stowage locker during a bench review at the Boeing Flight Equipment Processing Facility near the Johnson Space Center. Hands-on training such as this helps astronauts learn about equipment that is actually in space. NASA/JSC digital image dated June 23, 1994

Field exercises refer to experiential training that is used to provide crewmembers with real experiences as they learn specific behavioral skills. Examples include survival skills training in the outdoors and space simulation training in underwater habitats or isolation chambers. After these experiences, experts can provide input and feedback on self-management, teamwork, and leadership under extreme conditions. The main advantage of field exercises is that they provide all of the crewmembers with the opportunity to learn competencies that are directly related to the mission at the same time. In addition, field exercises allow the crewmembers to encounter and deal with their own weaknesses in a mission-like scenario.

Crew-oriented sensitivity training and team building have been used for decades in the aircraft industry and encompass such things as Line-Oriented Flight Training (LOFT) and Crew Resource Management (CRM) [1]. These approaches call for entire crews to work on simulated problems while they are observed by experts who are trained in group dynamics and performance evaluation. Feedback to the entire crew regarding their interpersonal interactions during the training session can be given afterwards, with recommendations for ways to improve team functioning. Nicholas [8] has suggested that such training should focus on three objectives: improvement of interpersonal skills, improvement of social support skills, and improvement of crew coordination skills. NASA uses a version of the CRM training that is called Space Flight Resource Management (SFRM) [9].

A comprehensive program for whole crew training has been described by Manzey et al. [10]. The main objectives of this training concern: (i) the support of the team-building process, (ii) the development of effective crew coordination skills, and (iii) the identification of strategies for coping with psychological issues that may arise in this specific crew during their common mission. The Manzey team described the use of this program during a 60-day spaceflight simulation conducted by the European Space Agency, where the approach was endorsed by the crewmembers during the post-mission debriefings.

8.2 IN-FLIGHT MONITORING

Monitoring the well-being of crewmembers during a mission includes tracking them over time for indications of medical, physiological, psychological, or interpersonal difficulties. In terms of the latter two, warning signs may include failure to pay attention to good hygiene, sleep problems, anxiety, depression, irritability, and withdrawal or poor interactions with their fellow crewmates. When such problems begin, it is important to initiate appropriate supportive activities to stabilize mood, improve relationships, and assist with performance. There are several kinds of monitoring activities.

8.2.1 Remote Monitoring from Earth

A variety of methods can be used for remote monitoring from Earth, but not all of them have been applied during space missions. Some are too invasive (e.g., analysis of blood chemistry using an indwelling catheter) or currently are too complex (e.g., brain function analysis via electroencephalography (EEG) measures). What typically has been done is less intrusive, such as periodic self-reports of emotional or cognitive state, random remote

audiovisual observations, or discussions between people on the ground and people in space [11]. For ISS operations, scheduled private psychological conferences between crewmembers and psychological experts in Mission Control have been used successfully by all international partner support teams to monitor the psychological status of the crewmembers for whom they are responsible.

One interesting monitoring approach involves wrist actigraphy (i.e., recordings of arm movements by means of an electronic watch-like device worn on the wrist) as an objective method for monitoring alertness and sleep—important issues for space travelers [12, 13]. This approach has been shown to be useful in research and during routine mission operations.

8.2.2 Voice Stress Analysis

The analysis of voice characteristics has been advocated as a useful indicator of the functional state of people working in ICEs [14, 15]. In this approach, experts monitor and analyze the structural parameters of verbal behavior (e.g., evaluation of length of talking time, number of words per unit of time) or the formal characteristics of speech itself (e.g., its rhythmic and structural properties, such as frequency and tone) to look for evidence of stress [1]. Several Russian researchers have reported success in using this method as an indicator of cosmonaut emotional state [16–18]. In contrast, an analysis by American researchers of the voice frequencies of selected Skylab communications was judged to be insufficiently predictive of crewmember stress to warrant further use [19]. One study of 17 male subjects in a laboratory found some promising results, but it did not reveal speech analysis to be as robust a stress indicator as other factors, such as heart rate [20].

More recently, the work of Johannes et al. [21, 22] has shown promise in this area. Their work has centered on measurements of the lowest frequency of voice pitch, the so-called fundamental frequency, which results from physiological vibrations in the glottis. In studies on the ground, they found that emotional excitation increased the mean level of the fundamental frequency and that voice pitch statistically differentiated people with sensitizing versus repressing personality traits. Due to individual variations, the investigators found it important to calibrate voice pitch to reflect individual reference characteristics. During a 135-day confinement study involving three men working in the Mir space station simulator in Moscow, they analyzed the speech of the crewmembers during a docking simulation [21]. Drops in the fundamental frequency were found when tasks were performed in a state of fatigue after 72 h of sleep deprivation.

Johannes and his colleagues [22] also analyzed voice pitch on the Mir space station. They concluded that the analysis of speech fundamental frequency could be used to monitor the psychophysiological state of people working in the space environment, provided that individual baseline calibrations were made to assess voice pitch and subjective perceptions of stress in each individual. However, it has not been possible to distinguish whether an elevated fundamental frequency of the voice results from workload stress or general states of positive or negative emotional arousal. This qualitative insensitivity limits the use of the speech analysis, and further work needs to be done in this area.

8.2.3 On-Board Monitoring

An alternative to remote crew monitoring is the implementation of an on-board monitoring approach. One method is to train one of the crewmembers to recognize potential problems when they occur and alert the crew or Mission Control when necessary. It is likely that the mission commander or designated crew medical officer will take on this responsibility and, in future expeditionary missions with large crews, a special psychologically trained member could serve as the psychosocial monitor. However, Nicholas [8] has pointed out that such a person could not remain completely objective and be unaffected by issues that influence the other crewmembers, since he or she also is part of the crew and would be exposed to the same stressors and group dynamic issues. Nicholas argues that all of the crewmembers should be trained to monitor and evaluate their interpersonal environment in order to be able to recognize early signs of psychosocial problems and to intervene if necessary.

A second approach to on-board monitoring includes the provision of formal self-monitoring tools for the crewmembers. An on-board neurocognitive assessment methodology has been tested by NASA during the Shuttle/Mir program and on the ISS. For example, a computerized Spaceflight Cognitive Assessment Tool for Windows (WinSCAT) has been developed [23–25]. It consists of five well-established and validated neuropsychological tests that probe different cognitive functions, including verbal memory, mental arithmetic, sustained attention, and spatial imagery and memory. Each performance assessment takes about 15 min, and it provides data that can be compared with baseline data established during pre-flight training. This gives the astronaut a quick overview about his/her cognitive state in space relative to the "normal" level exhibited on Earth, and it gives flight surgeons an objective assessment measure to use after a traumatic event (e.g., head injury, exposure to toxic gases). It could also be a useful tool to implement prior to initiating a sensitive operational activity that can be delayed if the participant is not functioning optimally at the time.

A similar tool that has been proposed for the self-monitoring of cognitive performance in space is the MiniCog Rapid Assessment Battery (MRAB) [14, 26]. Similarly to the WinSCAT, it consists of a set of different cognitive performance tasks that are presented on a personal digital assistant. It has been proposed as an "early warning" tool that can make astronauts aware of cognitive performance decrements before they produce decrements in work performance. This tool has not yet been implemented in the US Space Program.

One problem with such on-board monitoring methods is that they presuppose high trust in the autonomy, motivation, and honesty of each crewmember. They also require crewmembers to view them as helpful tools rather than "spying" activities that will affect their actions and future career plans. Although these tools may be appropriate for monitoring cognitive performance, fatigue, and specific neuropsychological functions after stressful events, their uses with respect to personality changes, mood, or interpersonal relations are limited at the present time.

8.3 IN-FLIGHT SUPPORT

Since the implementation of long-duration orbital spaceflight, the provision of psychological in-flight support to crewmembers has been an important countermeasure in Russia [1, 11, 27]. A psychological support group was established that coordinated different activities in order to counter feelings of monotony, isolation, and behavioral health issues like asthenia (see Sect. 2.4). Supportive activities have included surprise presents and favorite foods delivered via resupply vehicles, increased on-board music and lighting, increased contact with people on Earth, and ground-crew counseling or psychotherapy [28]. In addition, the arrival of visiting astronauts and cosmonauts has helped counter monotony and provided stimulation and assistance in performing mission activities. Learning from this experience, a similar system has been established by NASA and other space agencies for their astronauts [29, 30]. Examples of supportive activities that are used to improve morale and counter stress during long-duration near-Earth missions include:

- private psychological conferences with support staff on Earth;
- favorite foods and hobby equipment sent up via resupply vehicles;
- family-focused preparation and support;
- personal packages and letters sent up from family and friends;
- adequate on-board provision of leisure-time supplies.

8.3.1 Private Psychological Conferences

Specific psychological counseling or guidance to crewmembers during their time in space can help to ameliorate psychosocial stressors from adversely affecting individual or crew efficiency. One approach is to conduct private psychological conferences that involve two-way communication between individual crewmembers and psychological support staff on Earth on a regular basis during a space mission. The introduction of the Internet Protocol (IP) phone and the presence of relay satellites have allowed Earth-ground communications to occur nearly any time. Beyond their importance for crew monitoring, which has been discussed above, the main purpose of these conferences is to maintain continuous contact with the crewmembers in space and to offer them the opportunity to talk about their feelings and experiences during the mission, including individual adjustment problems or difficulties in their relationship with other crewmates or Mission Control.

For ISS crewmembers, these conferences have been implemented as a medical requirement, and they are considered to be a key countermeasure in the in-flight maintenance of crewmember behavioral health. This notion has been supported by empirical study. For example, Manzey et al. [31] evaluated 287 such conferences involving 16 astronauts in space. Only a few of the conferences (<15 %) were waived due to operational reasons or crewmember requests. The average duration of each conference was considerably longer (16.9 min) than the minimum allotted time of 10 min, with the longest lasting up to 45 min. These data may be taken as an indication of the high acceptance of this support tool by astronauts, which also is reflected in positive feedback during debriefing sessions.

Information gleaned from these conferences can result in the sending-up of favorite foods and presents to boost morale and counter loneliness and depression. Examples of

presents that can be loaded on resupply ships include family pictures, musical instruments, games, and other hobby equipment. In near-Earth environments, this countermeasure is fairly easy to implement but as we shall see in Chap. 9, this strategy becomes impractical on interplanetary missions, where the distance involved interferes with flexible and frequent resupply.

8.3.2 Family-Focused Preparation and Support

Contact with family members and friends can be very supportive for people working on orbit [32, 33] or in other ICEs, such as Antarctica [34]. Kelly and Kanas [32] found that astronauts and cosmonauts acknowledged the value of contact with loved ones on the ground as having a positive influence on mission performance. Space travelers who spent 20 or more total days in space endorsed the value of letters and other forms of contact with people on Earth significantly more than colleagues who spent less time in space [33], which suggests that supportive crew–ground interactions are even more beneficial during long-duration space missions.

The best way to maintain close contact between crewmembers in space and their social network on Earth is to provide communication on a frequent and regular basis. One important medium for this purpose is e-mail, which has been used frequently by crewmembers on the ISS for communicating with home. Private family conferences also have been established as part of the psychological support program. These conferences involve two-way video contacts between a crewmember and his/her family. They are scheduled every week for a minimum duration of 15 min for each crewmember. There also are scheduled opportunities to celebrate special family events (e.g., birthdays, anniversaries) and holidays. The communication lines used for these conferences are kept private and cannot be monitored by third parties in Mission Control.

One important supportive issue for crewmembers in space is the knowledge that their family members on Earth are healthy and happy. Therefore, it is important for the families to receive support as well. This can be done via family briefings, support during launch and landing, family conferences, or even individual counseling sessions as needed that are sponsored by the space agencies. In addition, informal support groups led by trained counselors or the family members themselves using a “peer-led” model have been utilized.

Of utmost importance is to provide family members with a clearly defined point of contact where they can get information about the progress of the mission, where they can send items that will be transported via resupply vehicles (e.g., letters, gifts, photos), and where they can ask for support for issues that arise while their family member is in space. Such support can help to maintain the crewmembers’ concentration on the mission tasks by relieving them from excessive worry about problems at home and feelings of abandoning their families during crises. This is suggested by comments from many astronauts that they are more concerned for the well-being of their family members on Earth than for their own well-being in space.

8.3.3 Leisure-Time Activities

One important aspect of psychological in-flight support is to prevent feelings of monotony, boredom, and isolation that could arise during missions with long periods of free time. Consequently, attention should be given to enhancing leisure-time activities, taking into account that the interests and needs of the astronauts may be subject to change. This is of particular importance after several weeks into the mission, when primary adaptation has been achieved, initial feelings of excitement of being in space have declined, and operational tasks have become routine.

What kind of leisure activities are preferred by astronauts on long-duration space missions? This question was addressed in a questionnaire survey by Kelly and Kanas [33]. Interest areas rated as being most helpful for filling free time included monitoring international and national events and reading about historical subjects. Topics related to sports, the arts, erotica, economics, and other areas of human activity were ranked lower. This preference for world news and historical issues was endorsed by significantly more cosmonauts than astronauts and significantly more long-duration than short-duration space travelers. Perhaps this reflects a perception by space travelers that their own mission activities were of international and historical importance, and this caused them to be more interested in similar events taking place on Earth. The Russian psychological support group has paid a great deal of attention to keeping cosmonauts informed about important events on Earth and even organizing audio or video contacts with interesting people, such as artists, politicians, and athletes.

A wide variety of supportive material for leisure-time activities is stocked on board spacecraft such as the ISS. Most of this material is individually defined well in advance of the mission and may consist of music, videos, books, recreational software, a variety of food choices, or other similar objects that meet defined size and weight requirements (Fig. 8.4). In addition, as crewmember interests change, additional leisure-time material can be delivered to orbiting crews via resupply flights.

8.4 POST-MISSION READAPTATION

Investigations of individuals returning from polar expeditions suggest that long-term stays in isolated environments are not necessarily associated with adverse long-term effects on subsequent health and performance [35]. However, problems of readjustment after return from a long-duration space mission can arise that might require psychological support.

8.4.1 Individual Issues

Readjustment to life on Earth after a long time in space can be assisted through debriefings at both the individual and the crew level. Some crewmembers may have had unpleasant psychosocial experiences in space that need to be addressed. For example, a crewmember who was scapegoated during a mission may have angry feelings post flight that may affect future interactions with his or her former crewmates. Other returning space travelers may have experienced personality changes as a result of being in space, in some cases

8.4 Musical instruments can provide enjoyable leisure-time activities for astronauts in space. Here, an astronaut plays his guitar on board the ISS during free time. NASA/JSC digital image dated December 16, 2011

becoming more humanistic, religious, or spiritual after observing the oneness of people on Earth or the infinity of the Cosmos [36]. Some returning individuals experience difficulty dealing with the resulting fame and glory of their mission, especially during a trailblazing activity like being the first person to travel in space or being part of the first crew to land on the Moon. Buzz Aldrin [37] has written about the readjustment problems he experienced after his lunar flight, which included clinical depression, substance abuse, and marital difficulties. This especially may be problematic for more private individuals who suddenly find themselves thrust into the spotlight and are required to go on the road to make appearances for the media or interest groups. These issues can be dealt with by debriefings, protected privacy during the readjustment period, and time off to relax and get used to living on Earth again.

8.4.2 Family Issues

A returning space traveler also may cause problems for the family. Studies have shown that many wives of male submariners learned to adjust to the absence of their sailor husband when he was on sea patrol, but over half of them experienced depression and marital strife after he returned and tried to reinsert himself back into the family dynamics. As was discussed in Sect. 2.7, this has led to the term "the submariners' wives syndrome" [38, 39]. Care needs to be taken that similar developments do not occur in the family of an astronaut after he or she returns from a long-duration space mission.

Support activities for family members should not only be provided during the mission, but they should also be offered in the post-mission period. These might include joint debriefings of crewmembers and their families by counselors who are trained to deal with the effects of separation on family life. Schedules should be arranged to allow crewmembers to reintegrate back into their social networks free from the public scrutiny that can add additional stress to the return home. Despite the fame and glory that accompany some space missions, involved individuals need private time to readjust both psychologically and physically to their family life on Earth.

REFERENCES

1. Kanas, N., & Manzey, D. (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA: Microcosm Press.
2. Kanas, N. (2013). Human interactions on-orbit. In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin: Springer.
3. Kring, J. P. (2001). Multicultural factors for international spaceflight. *Journal of Human Performance in Extreme Environments, 5*(2), 11–32.
4. Gushin, V., Zaprisa, N. S., Kolinitchenko, T. B., Efimov, V. A., Smirnova, T. M., Vinokhodova, A. G., et al. (1997). Content analysis of the crew communication with external communicants under prolonged isolation. *Aviation, Space, and Environmental Medicine, 68*, 1093–1098.
5. ISS Mission Operations Directorate ITCB Training Working Group. (2007). *Human behavior and performance competency model guide (JSC-63837-basic)* (Vol. I). Houston, TX: Johnson Space Center.
6. ISS Mission Operations Directorate ITCB Training Working Group. (2007). *Human behavior and performance competency model guide (JSC-63837-basic)* (Vol. II). Houston, TX: Johnson Space Center.
7. Picano, J. J. (1990). An empirical assessment of stress-coping styles in military pilots. *Aviation, Space, and Environmental Medicine, 61*, 356–360.
8. Nicholas, J. M. (1989). Interpersonal and group-behavior skills training for crews on space station. *Aviation, Space, and Environmental Medicine, 60*, 603–608.
9. Rogers, D. G., Jenkins-Todd, D., Kempton, R., Miller, B., Bauer, J., Dillon, S. F., et al. (2002). *NASA's space flight resource management program: A successful human performance error management program*. Houston, TX: Barrios Technology/United Space Alliance. http://arc.aiaa.org/doi/pdf/10.2514/6.2002-T4-12.
10. Manzey, D., Schiewe, A., & Fassbender, C. (1995). Psychological countermeasures for extended manned spaceflights. *Acta Astronautica, 35*, 339–361.
11. Kanas, N. (1991). Psychosocial support for cosmonauts. *Aviation, Space, and Environmental Medicine, 62*, 353–355.
12. Monk, T. H., Buysse, D. J., & Rose, L. R. (1999). Wrist actigraphy measures of sleep in space. *Sleep, 22*, 948–954.
13. Mollicone, D. J., van Dongen, H. P. A., & Dinges, D. F. (2007). Optimizing sleep/wake schedules in space: Sleep during chronic nocturnal sleep restriction with and without diurnal naps. *Acta Astronautica, 60*, 354–361.
14. Lieberman, P., Morey, A., Hochstadt, J., Larson, M., & Mather, S. (2005). Mount Everest: A space analogue for speech monitoring of cognitive deficits and stress. *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B198–B207.
15. Ruiz, R., Legros, C., & Guell, A. (1990). Voice analysis to predict the psychological or physical state of a speaker. *Aviation, Space, and Environmental Medicine, 61*, 266–271.
16. Gazenko, O. G., Myasnikov, V. I., & Uskov, F. N. (1976). Behavioral control as a tool in evaluating the functional state of cosmonauts in flight. *Aviation, Space, and Environmental Medicine, 47*, 1226–1227.

17. Khachaturyants, L., & Grimak, L. (1972). Emotional stress during spaceflight. *Aviation Kosmonautica, 11*, 33–34 (JPRS OPBS 58039).
18. Simonov, P. V., & Frolov, M. V. (1973). Utilization of human voice for estimation of man's emotional stress and state of attention. *Aerospace Medicine, 44*, 256–258.
19. Older, H. J., & Jenney, L. L. (1975). *Psychological stress management through voice output analysis. NASA CR 147723*. Alexandria, VA: Planar.
20. Brenner, M., & Shipp, T. (1987). Voice stress analysis. In J. R. Construck (Ed.), *Mental-state estimation 1987*. Washington, DC: National Aeronautics and Space Administration/NASA Conference Publications.
21. Johannes, B., Salnitzki, V. P., Haller, H., Wilke, D., Fischer, F., & Schlykova, L. (1995). Comparison of voice stress reactivity under psychological stress and simulated Mir docking maneuver. *Journal of Gravitational Physiology, 2*, P107–P108.
22. Johannes, B., Salnitski, V. P., Gunga, H.-C., & Kirsch, K. (2000). Voice stress monitoring in space: Possibilities and limits. *Aviation, Space, and Environmental Medicine, 71*, A58–A65.
23. Kane, R. L., Short, P., Sipes, W., & Flynn, C. F. (2005). Development and validation of the Spaceflight Cognitive Assessment Tool for Windows (WinSCAT). *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B183–B191.
24. Retzlaff, P., & Vanderploeg, R. (2000). Validating the spaceflight cognitive assessment tool against other neurocognitive measures in young adults [abstract]. *Proceedings of the 71th Annual Meeting of the Aerospace Medical Association, Houston*, May.
25. Retzlaff, P., Flynn, C., Glode, B., & Lane, B. (1999, August 19–24). *Space cognitive assessment tool: Description and cut scores*. Paper presented at the American Psychological Association Annual Meeting, Boston, MA.
26. Shephard, J. M., & Kosslyn, S. M. (2005). The MiniCog rapid assessment battery: Developing a "blood pressure cuff for the mind". *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B192–B197.
27. Grigoriev, A. I., Kozerenko, O. P., & Myasnikov, V. I. (1987). *Selected problems of psychological support of prolonged space flights*. Paper presented at the 38th Congress of the International Astronautical Federation, Stockholm, Sweden.
28. Kanas, N. (1998). Psychiatric issues affecting long duration space missions. *Aviation, Space, and Environmental Medicine, 69*, 1211–1216.
29. Flynn, C. F. (2005). An operational approach to long-duration mission behavioral health and performance factors. *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B42–B51.
30. Sipes, W. E., & Vander Ark, S. T. (2005). Operational behavioral health and performance resources for International Space Station crews and families. *Aviation, Space, and Environmental Medicine, 76*(6 Suppl.), B36–B41.
31. Manzey, D., Carpenter, F., Beven, G., Sipes, W., Vander Ark, S., & Salnitzkiy, V. (2007, May 20–24). *Private psychological conferences for long duration space missions*. Paper presented at the 16th Human in Space Symposium, Beijing, China.
32. Kelly, A. D., & Kanas, N. (1993). Communication between space crews and ground personnel: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 64*, 795–800.
33. Kelly, A. D., & Kanas, N. (1994). Leisure time activities in space: A survey of astronauts and cosmonauts. *Acta Astronautica, 32*, 451–457.
34. Palinkas, L. A., Gunderson, E. K. E., Holland, A. W., Miller, C., & Johnson, J. C. (2000). Predictors of behavior and performance in extreme environments: The Antarctic space analogue program. *Aviation, Space, and Environmental Medicine, 71*, 619–625.
35. Palinkas, L. A. (1986). Health and performance of Antarctic winter-over personnel: A follow-up study. *Aviation, Space, and Environmental Medicine, 57*, 954–959.
36. Kanas, N. (1990). Psychological, psychiatric, and interpersonal aspects of long-duration space missions. *Journal of Spacecraft and Rockets (AIAA), 27*, 457–463.
37. Aldrin, E. E. (1973). *Return to Earth*. New York: Random House.
38. Isay, R. A. (1968). The submariners' wives syndrome. *Psychiatric Quarterly, 42*, 647–652.
39. Pearlman, C. A., Jr. (1970). Separation reactions of married women. *American Journal of Psychiatry, 126*, 946–950.

Section II

Interplanetary and Interstellar Missions

9

Autonomy and the Crew–Ground Interaction

9.1 CREW–GROUND INTERACTIONS

Given the tremendous distances involved, expeditions to other planets will result in communication time delays and the inability to resupply or rescue crewmembers at short notice in the event of an emergency. This means that the crews will have to respond to their own crises and develop ways of dealing with the mission objectives autonomously. In contrast, during near-Earth missions on orbit or to the Moon, people on Earth still will be involved with mission planning and provide important support for crewmembers. Let's take a closer look at the crew-ground relationship under conditions of high autonomy.

Currently, Mission Control personnel develop the schedules and provide assistance in solving problems that occur in space (Fig. 9.1). If they are not sensitive to the specific demands and needs of a space crew, there is a danger that they may overload them with activities or misinterpret their requests. In their survey of 54 astronauts and cosmonauts who had flown in space, Kelly and Kanas [1] found that the respondents rated a shared experience and a mutual excitement for spaceflight as two factors that significantly helped with crew–ground communication.

But at times, people in isolated and confined environments (ICEs) want to take over responsibility for mission activities and prefer to separate from the influences of outside monitoring personnel. For example, during two space analog studies that took place in Moscow, one for 90 days and one for 135 days, Gushin et al. [2] analyzed the communication frequencies and patterns between the crewmembers and outside monitoring personnel. The results suggested that the isolated crews were becoming more autonomous and were screening the information they communicated outwardly over time (this was labeled "psychological closing"—see Sect. 4.8). In addition, the communication patterns varied with different outside teams that were scheduled to be on duty. The investigators concluded that their ICE crews became more self-sufficient and preferred to rely on their own resources due to the isolated living conditions. Results such as these suggest that space mission planners need to consider crew autonomy as an important factor for long-duration missions.

Problems related to lack of empathy, over-scheduling, or insensitivity to autonomy needs can lead to crew–ground miscommunication and perceived lack of support that can

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_9

9.1 During near-Earth space activities, Mission Control centers provide useful real-time monitoring and supportive activities. This image shows the Johnson Space Center Mission Control Center tracking a Space Shuttle mission. NASA/JSC digital image dated December 22, 1999

negatively impact on the mission. In their survey of nine astronauts, Santy et al. [3] found three reported incidents of miscommunication, misunderstanding, or interpersonal conflict that involved the crewmembers' interactions with people on the ground. Also, in Sect. 4.8, we have seen how crew tension can lead to the displacement of negative emotions onto outside personnel, thus contributing to crew–ground miscommunication.

9.2 AUTONOMY AND COMMUNICATION DELAYS DURING INTERPLANETARY MISSIONS

Autonomy is defined as the level of discretion and freedom an individual or team is given to perform tasks, including decision making and problem solving, as well as other general duties [4]. In organizational research studies on the ground, autonomy has been found to positively influence employee ownership of problems, role breadth, and performance [5];

improve team cohesion and well-being [4, 6]; lead to increased active learning and decreased emotional exhaustion [7]; and negatively relate to personal strain [8]. Generalizing from these findings, increased autonomy in space might be expected to improve performance and cohesion and decrease fatigue and stress. However, working in space and in other ICEs may produce new stressors not present in typical work environments on Earth, so it is difficult to make such generalizations.

As planning takes place for missions to distant planets and other Solar System bodies (e.g., asteroids, comets, planetary moons), it is apparent that increased crew autonomy will need to be factored in. A major reason for this relates to the vast distances involved and the resulting communication delay between space travelers and Earth. For example, although moving at the speed of light, the two-way transmission time of a conversation between Earth and Mars can be over 40 min, depending on the positions of the two planets relative to each other (i.e., both relatively close on the same side of the Sun, or opposite each other with the Sun in between). This delay will prohibit real-time communication and limit the effectiveness of operational discussions with Mission Control and supportive conversations with family and friends (Fig. 9.2). In addition, scheduled resupply events will be rare, and the possibility of an emergency resupply or medical evacuation of a sick member of the crew will be impossible. This will force crewmembers to function more on their own and deal with problems and operational issues in a highly autonomous manner.

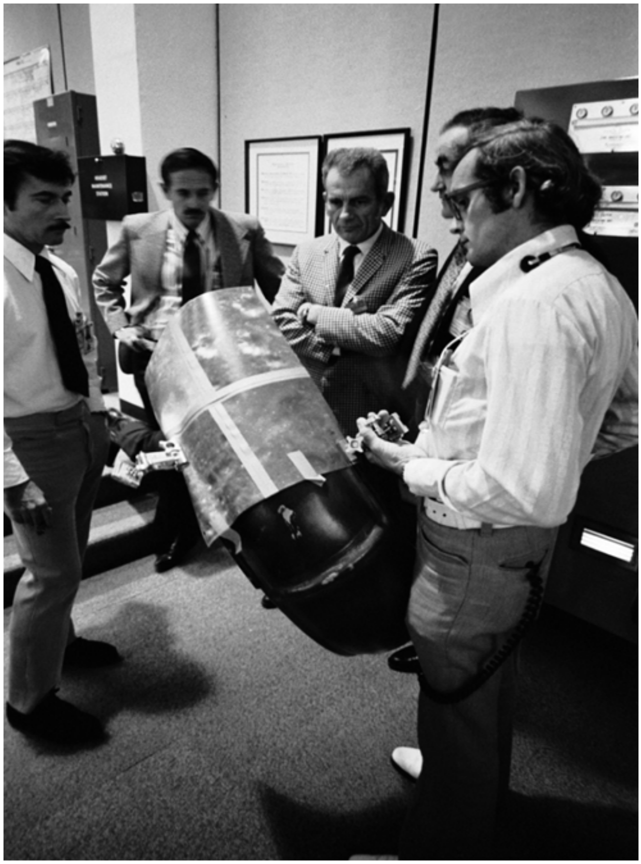
9.3 SPACE SIMULATION STUDIES OF HIGH VERSUS LOW AUTONOMY

My colleagues and I [9] have studied some of these issues during a series of space simulation experiments aimed at examining the effects of high versus low crew autonomy on crewmember mood, group interpersonal climate, cohesion, task performance, and the crew–Mission Control interaction. Although the generalizability of the results were constrained due to small crew size and limited statistical power, these pilot studies nevertheless were a beginning in examining important factors in preparation for future long-duration space missions where autonomy would be important. Three ICEs were studied using many of the same measures as we used in our Mir and International Space Station (ISS) studies (see Sect. 2.2).

9.3.1 NEEMO 12 and 13

The first involved the NASA Extreme Environment Mission Operations (NEEMO) program. The purpose of this program is to provide space mission execution experience using the Aquarius underwater laboratory, which is located off the coast of Florida. Missions typically last 10–14 days and involve research and other activities conducted by four or more "aquanauts," many of whom are astronauts or other NASA personnel. "Mission Control" personnel located topside monitor crewmember progress and timeline the schedule (Fig. 9.3).

We studied two NEEMO missions: 12 and 13 [9]. NEEMO 12 consisted of 12 days of low autonomy, where the crewmember work schedules were timelined by Mission Control. Subjects included three NASA crewmembers and six topside personnel. NEEMO 13



9.2 In past space missions, people on Earth have provided real-time support to space crews during times of crisis. Here, a group of NASA Mission Control experts ponders ways to repair damage that occurred to a Lunar Roving Vehicle during Apollo 17. In interplanetary missions, the time distances and communication delays will make real-time support from Earth less practical, and the crews will have to deal with emergencies and problems themselves. NASA/ JSC digital image dated December 11, 1972

comprised 4 days of low autonomy and 6 days of high autonomy, where the crewmembers had more flexibility to plan their own work schedule and experienced a 40-min two-way communication delay with Mission Control. Subjects included four NASA crewmembers and eight topside personnel.

Our results suggested that the high-autonomy condition was successfully employed in NEEMO 13 with no adverse results. There seemed to be clear differences between the low- and high-autonomy periods on some subscales that tended to favor the latter condition. For example, the crewmembers reported more direction from the mission commander (reflected by an increased score in a measure of the task role of the leader) and a decrease in fatigue from the low- to the high-autonomy period during NEEMO 13 as compared to

9.3 NASA Extreme Environment Mission Operations (NEEMO) Mission #12 crewmembers heading for the Aquarius submersible during a training session. Both land-based and undersea space analog habitats like the Aquarius provide a good training ground for actual space missions. NASA/JSC digital image dated May 2, 2007

NEEMO 12, which was conducted under low autonomy. For the topside subjects, role confusion increased during the high-autonomy period of NEEMO 13 as compared to the second half of NEEMO 12, where it declined, suggesting that the topside personnel were not as clear in their roles when the crew took over more of the schedule.

9.3.2 HMP 2008

Our second study involved some of the summer 2008 crewmembers working on the Haughton-Mars Project (HMP) on Devon Island in Canada. The location was an old, large impact crater that had similarities to the Martian surface in terms of appearance and geological characteristics. People participating in this program dressed up in spacesuits, traveled in a Mars rover, and conducted tasks similar to those anticipated during an actual expedition to Mars. There was no formal "Mission Control" and the participants had great freedom to plan their activities each day. Hence, there was a high level of group autonomy in terms of planning work activities.

We studied eight non-NASA scientists and graduate students who worked in this setting during the last 3 weeks of their stay [9]. The subjects reported significantly higher levels of cohesion, innovation, and guidance from their leader as compared with other work groups on Earth. They also reported less need for outside supervision. Taken together, these results suggested that these people working under relatively high autonomous conditions were not adversely affected and may have been more creative than other work groups on Earth.

9.3.3 Mars 500 105-Day Pilot Study

Our last study was part of the Mars 500 Project. This program was designed to study the performance and interactions of a group of six individuals engaged in a simulated mission to Mars. The simulator was located at the Institute for Biomedical Problems (IBMP) in Moscow. The lower floor consisted of living and laboratory modules for the crew, and the upper floor contained a mock-up of the Mars surface. More will be said of this 500-day mission in Sect. 10.2.

As a trial run, a 105-day pilot simulation was conducted in 2009 that involved a crew of six men: two Russian cosmonauts (one of whom was the commander), a Russian medical doctor, a Russian sports physiologist, a German mechanical engineer, and a French airline pilot. During their mission, they simulated a number of scenarios related to launch, the outbound journey to Mars, and working on the Martian surface. During the first two-thirds of the mission, the crew interacted in real time with outside monitoring staff ("Mission Control") during low-autonomy conditions, but during the last third, they had more responsibility for monitoring and planning their own activities and experienced a two-way Mars-like communication delay with the outside—the high-autonomy condition.

The results suggested that the crewmembers found high autonomy to be a positive experience that allowed them to depend less on direction from their commander or outside supervisors than in the low-autonomy condition. The four Russian subjects perceived more work stress under the less structured high-autonomy condition than under the more structured low-autonomy condition. However, on several measures of negative mood, the two European crewmembers showed a rise during the high-autonomy condition, whereas the Russians scored the same or slightly improved. The Russians perceived a rise and the Europeans a drop in cohesion during high versus low autonomy.

The reactions of Mission Control subjects to different autonomy conditions also were examined. Similarly to the NEEMO findings reported above, these outside monitors experienced more tension and confusion and less task orientation during high autonomy, probably as a result of having less clear work goals and tasks to perform.

9.3.4 Gushin 105-Day Pilot Study

Gushin and his colleagues also participated in the Mars 500 105-day study. They used the Personal Self Perception and Attitudes (PSPA) psychosocial test to assess crew cohesion, individual personal values, and group identification. They also conducted a content analysis of the crewmembers' daily audio communication with Mission Control and their on-duty daily written reports [10].

The content analysis of the crewmember communication with Mission Control suggested that the crew experienced some work pressure, especially the Russians during the high-autonomy condition. There were complaints about not having enough time for tasks, and the crewmembers noted a lack of task orientation from the Mission Controllers in at least 10 % of the daily reports and 5 % of the communication sessions. There was less crew interaction than in previous analog studies conducted by this research team (e.g., crewmembers sometimes didn't inform each other about instructions they had received from Mission Control). According to visual observations from Mission Control and results from the PSPA, crewmembers often spent time alone or in subgroups, such as during meal times. They were physically and psychologically distant from each other, and there was not enough leader direction and guidance in the international crew.

Based on a content analysis of the Russian crewmember post-mission debriefs, they acknowledged having less opportunity to vent (i.e., displace) anger to the outside during the high-autonomy period due to the lack of general communication, so they felt that interpersonal tension accumulated within the crew. One Russian subject felt "all alone without enough information and support." Nevertheless, the Russian and European crewmembers generally liked the autonomy period, since it gave them a chance to escape from task demands from the outside.

During their post-mission debriefs, the Mission Control subjects reported that they detected more delays and even drops in mission task accomplishment during the high-autonomy period from the Russian crewmembers, which they attributed to their inability to remind them about the tasks. Such delays and omissions were not found among the European subjects.

9.3.5 Sandal 105-Day Pilot Study

Sandal and her colleagues also participated in the Mars 500 105-day project. Their study looked at the effect of isolation on changes in personal values. A major goal of the study was to look for the presence of "groupthink," which is the tendency of a group to strive for consensus at the cost of considering alternative courses of action [11].

The investigators collected monthly data on the implications of differences in personal values for crew cohesion and tension over time using the Portraits of Crew Values Questionnaire (PCVQ). In addition, semi-structured, individual interviews were conducted before and after the confinement period. Topics addressed during these interviews included sources of tension between crewmembers and between the crew and Mission Control, and changes in stress and coping strategies during low autonomy versus high autonomy.

Results from the PCVQ revealed the presence of intra-crew tension that was attributed to differences in values of hedonism, benevolence, and tradition in the last 35 days, when the crew was given more autonomy. Subgroups were identified in terms of personal values, and there was no evidence for "groupthink." The investigators concluded that personal values should be considered as factors in composing crews for future long-duration space missions.

Data from the post-confinement interviews suggested that, in general, the crewmembers perceived low levels of intra-crew tension and a desire to get along with one another. The general tension that did exist was related to the quality and quantity of the food, work

coordination (perhaps due to cultural differences), and the lack of task orientation in the leadership of the commander. Although relations with Mission Control were described as generally good, several crewmembers indicated rising tension and frustration in relation to Mission Control members before the high autonomous conditions were implemented. Some crewmembers felt that Mission Control was not sufficiently sensitive to their needs (e.g., when they asked for permission to change their diet) and they felt infantilized when these monitoring personnel did not provide justification for some of their decisions. For these crewmembers, the reduction in contact with the outside was seen as a “relief.” Most crewmembers described the atmosphere within the chambers as being “calmer” during the high-autonomy condition, which allowed them to focus more on their work.

9.3.6 Computer Space Simulation Activities and Autonomy

Roma et al. [12] used a novel laboratory-based computer simulation model to assess crew performance, biopsychosocial adaptation, and autonomy. In two separate experiments involving 33 research volunteers, three-member groups were trained to conduct computer-simulated geological exploration missions lasting 3–4 h on a planetary surface. Each team member was assigned to a vehicle—orbiter, lander, or rover—that was operated via an individual workstation. The crewmembers needed to coordinate their activities with each other in order to navigate the simulated planetary surface and collect geological samples. Some of the missions were directed by Mission Control, whereas in others, the crewmembers were free to establish their own protocols for exploration and received only minimal baseline support from Mission Control. In the second experiment, some of the mission scenarios included an “unexpected” loss of audio and text-messaging function, enhancing the degree of crew autonomy. The mission performance of the crewmembers and all of their communication exchanges were recorded by the computer simulation program. In addition, salivary cortisol samples were collected pre, mid, and post mission as an indication of subject stress, and self-report questionnaires and post-mission debriefing logbooks were completed to obtain subjective feedback from the participants about their activities.

The results indicated that under autonomous conditions, there was improved task performance (as indicated by the retrieval of more highly valued geological samples), increased self-reporting of positive mood, fewer references to negative emotions, attenuated physiological stress reactivity (as determined by lowered salivary cortisol levels), and greater use of socially referent language in the post-mission debriefing log reports. The research team concluded that there was a causal relationship between crew autonomy and improved task performance, better psychosocial adaptation and group cohesion, and sustained biobehavioral health.

9.3.7 Conclusions

It must be emphasized that except for the Roma team experiments, the other studies summarized above were exploratory in nature, with small subject samples and limited statistical power. They need to be replicated using larger subject samples, preferably during actual space missions. But taken together, the above studies suggest that crews working in space simulation conditions on Earth perform well under conditions of high autonomy and

may even prefer the freedom of this condition to low autonomy. Although there may be a drop in efficiency, there is improved morale and perceptions of mood. There is a suggestion of cultural differences in perceived work pressure, however, which needs to be explored further during future studies. In addition, since there is less work for outside monitoring personnel to do under high-crew-autonomy conditions, attention needs to be given to the proper role of support staff back home during long-distance expeditionary space missions.

REFERENCES

1. Kelly, A. D., & Kanas, N. (1993). Communication between space crews and ground personnel: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 64*, 795–800.
2. Gushin, V. I., Zaprisa, N. S., Kolinitchenko, T. B., Efimov, V. A., Smirnova, T. M., Vinokhodova, A. G., et al. (1997). Content analysis of the crew communication with external communicants under prolonged isolation. *Aviation, Space, and Environmental Medicine, 68*, 1093–1098.
3. Santy, P. A., Holland, A. W., Looper, L., & Marcondes-North, R. (1993). Multicultural factors in the space environment: Results of an international shuttle crew debrief. *Aviation, Space and Environmental Medicine, 64*, 196–200.
4. Leach, D. J., Wall, T. D., Rogelberg, S. G., & Jackson, P. R. (2005). Team autonomy, performance, and member job strain: Uncovering the teamwork KSA link. *Applied Psychology: An International Review, 54*, 1–24.
5. Morgeson, F. P., Delaney-Klinger, K., & Hemingway, M. A. (2005). The importance of job autonomy, cognitive ability, and job-related skill for predicting role breadth and job performance. *Journal of Applied Psychology, 90*, 399–406.
6. Rasmussen, T. H., & Jeppesen, H. J. (2006). Teamwork and associated psychological factors: A review. *Work & Stress, 20*, 105–128.
7. Van Mierlo, H., Rutte, C. G., Vermunt, J. K., Kompier, M. A., & Doorewaard, J. A. C. M. (2007). A multi-level mediation model of the relationships between team autonomy, individual task design and psychological well-being. *Journal of Occupational and Organizational Psychology, 80*, 647–664.
8. Bakker, A. B., Demerouti, E., & Euwema, M. C. (2005). Job resources buffer the impact of job demands on burnout. *Journal of Occupational Health Psychology, 10*, 170–180.
9. Kanas, N., Saylor, S., Harris, M., Neylan, T., Boyd, J., Weiss, D. S., et al. (2010). High vs. low crewmember autonomy in space simulation environments. *Acta Astronautica, 67*, 731–738.
10. Kanas, N., Gushin, V., & Yusupova, A. (2008). Problems and possibilities of astronauts: Ground communication content analysis validity check. *Acta Astronautica, 63*, 822–827.
11. Sandal, G. M., Bye, H. H., & van de Vijver, F. J. R. (2013). The risk for groupthink during long-duration space missions: Results from a 105-day confinement study. In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin, Germany: Springer.
12. Roma, P. G., Hursh, S. R., Hienz, R. D., Brinson, Z. S., Gasior, E. D., & Brady, J. V. (2013). Effects of autonomous mission management on crew performance, behavior, and physiology: Insight from ground-based experiments. In D. A. Vakoch (Ed.), *On orbit and beyond: Psychological perspectives on human spaceflight*. Berlin, Germany: Springer.

10

Mission to Mars

Mars is a likely target for the first interplanetary mission. Because of its highly eccentric orbit and nearly 23-month-long year, it has a favorable opposition to Earth about every two years, when it is relatively close to us on the same side of the Sun. Especially during these times, its surface features have been observable through telescopes. We know that its polar caps contain water, and ever since the canal craze of the late 1800s and early 1900s, there has been speculation that life may exist on the Red Planet (Fig. 10.1). Although canals built by intelligent life forms have been debunked as products of optical illusions and a fertile imagination, gullies have been spotted on the surface indicating that running water was present on Mars in the not-too-distant past (Fig. 10.2). Also, landers on the surface have not completely ruled out the presence of microscopic life, so Mars continues to be of great interest to us.

Current planning for a Mars expedition in the 2030s envisions a mission duration of between two and three years and a crew of six or seven people [1]. Being confined with the same individuals for such a long period of time millions of miles from Earth may create psychological and interpersonal stress for the crewmembers and affect their ability to carry out mission goals. People have been on orbit for as long as 14 months with no apparent negative sequelae. However, this duration was relatively brief compared to a Mars mission, the orbiting crew had real-time communication with Mission Control and family and friends on the ground, immediate evacuation was an option, and Earth was always in sight. Nevertheless, to fully appreciate the psychosocial and psychiatric issues affecting a Mars crew, it is important to begin by examining some of the unique stressors of an expedition to the Red Planet.

10.1 UNIQUE PSYCHOSOCIAL STRESSORS OF A MARS EXPEDITION

The first part of this book dealt with the stressors and stresses related to near-Earth space missions, such as to an on-orbit vehicle or involving a lunar base. However, the great distances involved in a Mars expedition result in unique additional psychosocial stressors, which include:

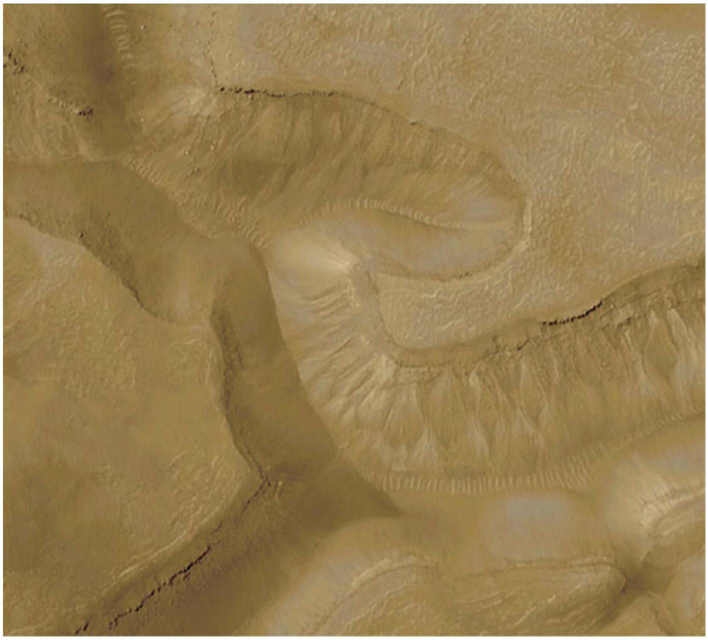
- selection issues: who will go?
- cultural issues;
- effects of long-term microgravity;

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_10

10.1 Map of Mars, from the 1909 second printing of Percival Lowell's *Mars as the Abode of Life*, first published in 1908. Note the extensive canal system and the dot-like oases located at their intersections. Lowell thought that these were canals built by intelligent Martians to bring water from the poles to the parched deserts of the Red Planet. We now know that these canals were the product of optical illusions and a fertile imagination. Courtesy of the Nick and Carolynn Kanas collection; and *Solar System Maps: From Antiquity to the Space Age*, Nick Kanas, Springer/Praxis, 2014

- effects of long-term exposure to space radiation;
- extreme isolation and loneliness;
- increased autonomy;
- lack of support due to communication delays;
- dependence on machines and local resources;
- limited social contacts and novelty;
- leisure time;
- Earth-out-of-view phenomenon;
- sexual issues.

In terms of crew selection, not everyone in the astronaut corps will want to be away from their family and friends for up to three years. Consequently, this may skew the pool

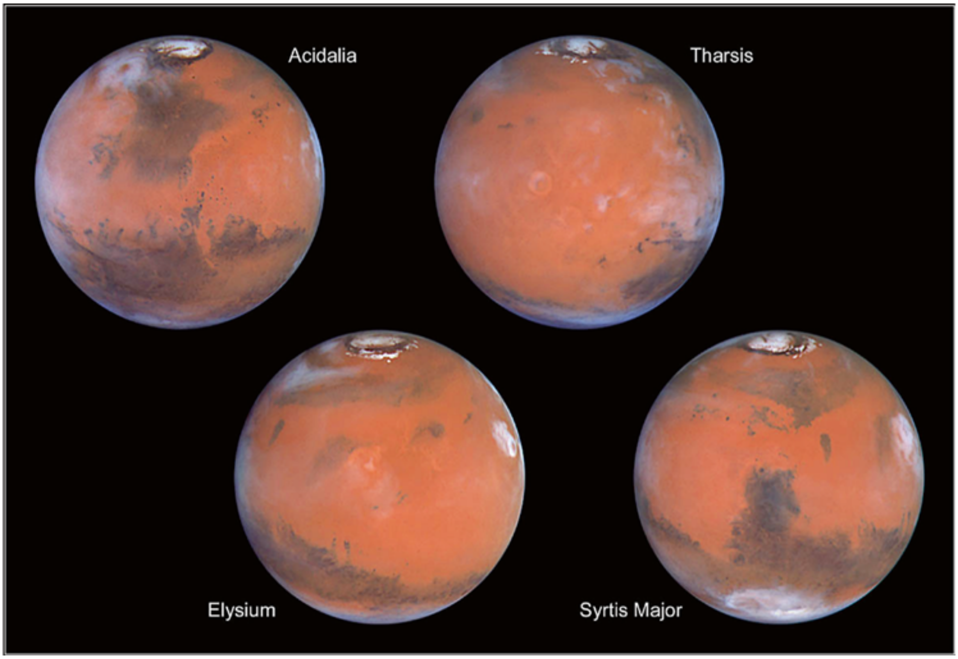


10.2 An image of a large trough on Mars taken by the Mars Global Surveyor in May 2000. Note the presence of gullies running down the slope, suggesting that that they carried running water in the not-too-distant past, perhaps within the last 100 years. NASA/GRIN/JPL digital image

of volunteers to specific types of individuals. Examples include single people, people without small children, or childless couples. The selection process will be compounded by the specific crewmember requirements of the mission, which will necessitate that people who are selected are experts in areas involving piloting, navigation, computer programming, engineering, geology, biology, and medicine. Financial and political considerations will require that the crew be composed of both men and women and have international representation (likely weighted toward countries that will foot most of the bill for this expensive venture).

Some of the cultural issues related to multinational space missions were discussed in Chap. 5. Specifically with regard to a Mars expedition, Nechaev et al. [2] surveyed 11 cosmonauts regarding their opinions of possible psychological and interpersonal problems that might occur during the mission. They found the following factors to be rated highly: isolation and monotony, distance-related communication delays with Earth, leadership issues, differences in space agency management styles, and cultural misunderstandings within the international crew. Some of these topics will be considered below.

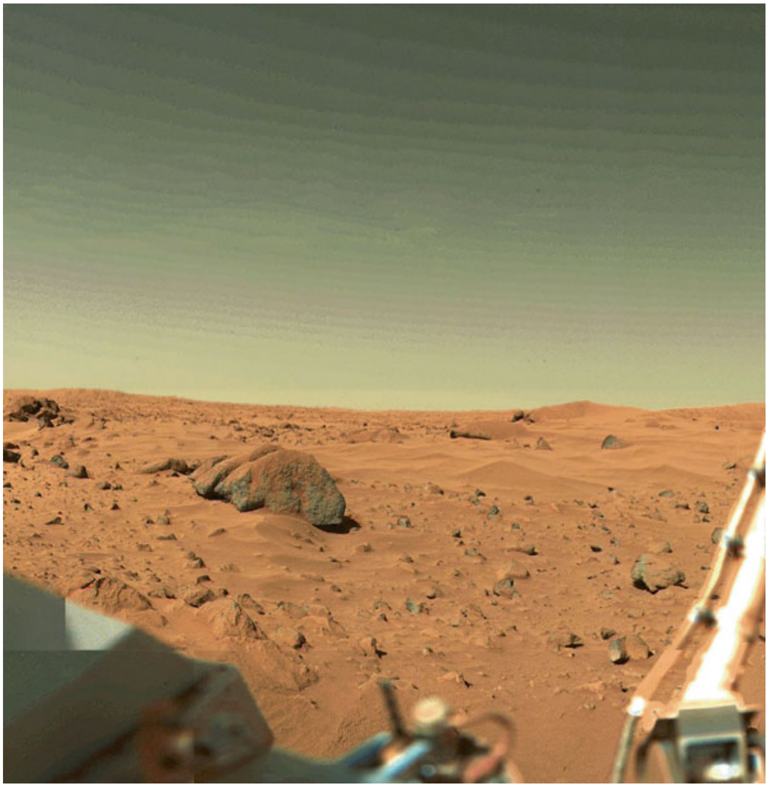
Little is known about the physiological, cognitive, and psychosocial impact of long-duration microgravity and high radiation in deep space, as well as the 38 % Earth gravity that the crew will experience on Mars. As can be seen in Fig. 10.3, Mars is a very exotic planet, with the Solar System's largest volcano, approaching 26 km (around 16 miles) in



10.3 Four views of the surface of Mars taken by the Hubble Space Telescope between April 27 and May 6, 1999. The north polar cap is at the top. Note the long Valles Marineris canyon system in the upper-left image and the Tharsis Plateau in the upper-right image with its mighty Olympus Mons volcano. NASA/NSSDC digital image, with collaboration from S. Lee, University of Colorado; J. Bell, Cornell; and M. Wolff, Space Science Institute

height, and a huge canyon system more than 3,000 km (around 1,800 miles) long. The surface of Mars is uninviting. It essentially is a cold, dry desert with a thin oxygen-depleted atmosphere that poorly blocks radiation from space (Fig. 10.4). Working on the surface of the Red Planet certainly will be a challenge. In order to prepare for the physical stressors of the Martian surface, visiting a colony on the Moon or making a brief trip to a near-Earth asteroid would allow the crewmembers to practice dealing with some of the issues related to living on a hostile planetary surface.

The Mars crew will be millions of miles away from Earth, and this will increase their sense of isolation and loneliness to levels greater than in any previous space mission. Some of the issues discussed in the last chapter related to the increased autonomy and delayed communications with Mission Control personnel and family and friends on Earth will enhance the sense of being isolated. If Earth and Mars are at their extreme orbital distance from each other on opposite sides of the Sun, it will take over 40 min for a question and an answer to be transmitted between the two sites. This essentially prohibits real-time conversations, and crewmembers will have to deal with operational and medical issues on their own.



10.4 A panorama of the Martian surface taken by the Viking 1 lander after it touched down on July 20, 1976. Note the barren desert-like landscape covered with rocks. Courtesy of NASA/NSSDC, with collaboration from M.A. Dale-Bannister, Washington University in St. Louis

People on a Mars expedition will be heavily dependent on computers and other machines on board for basic life support and operational activities, such as navigation and propulsion. The psychology of this dependence and the ergonomic characteristics of the human–machine interface are important issues to be considered in designing Martian space vehicles and habitats. Since not all supplies and fuel can be stored on board, the crew will need to rely on multiple pre-planted caches of supplies that are landed on Mars before the manned mission or depend on local resources in the atmosphere and the surface of Mars to chemically generate water and fuel for the return home. So again, the ease of use and reliability of the relevant equipment will be critical.

Direct human contact will be limited to just the crewmembers, and ennui may result from the lack of novelty and the predictability of interacting with the same people for years. People will have to find ways of learning new things about each other in order to find ways of relating that keeps the spark going for a long period of time. But they also will need to find meaningful things to do on their own. This will make leisure-time activities

important. Provisions will need to be available to accommodate a variety of free-time activities and hobbies. In addition, since some crewmembers may tire of the same activities or find that their interests are changing, the pool of leisure-time supplies needs to be variable and flexible enough to account for changing interests.

Even during on-orbit and lunar missions, no human being has ever viewed Earth as an insignificant dot in the heavens. The psychological impact of viewing our home planet in this way has been termed the "Earth-out-of-view phenomenon" [1]. The impact of seeing one's home reduced to a distant dot in the heavens may enhance the sense of isolation and homesickness. It also is possible that more serious effects will occur, such as depression, psychosis, or even suicidal thinking. We must be prepared for the occurrence of such reactions to this unprecedented event.

Over the course of nearly three years, things will change in one's family as children grow up and family members experience illness or even death. It is desirable for astronauts and their families to keep in touch and for space travelers to have a sense that their loved ones are being looked after. Some of these issues were discussed in Sect. 8.3.2, but they will become even more important in such a long and distant mission as an expedition to Mars. Complicating this issue is that the delayed communication will further enhance a sense of separation from important events occurring with family and friends back home.

One final interpersonal issue deserves mention. Sexual tensions in space were discussed in Sect. 4.5. In a multiyear space expedition involving sexually active men and women, it would be expected that sexual attraction and tension (both physical and psychological) will exist. How this will be dealt with is unclear at present, but it needs to be addressed. One idea is that a Mars crew should be composed of paired couples. However, adding this variable into the selection process would further complicate an already complex situation, with many competing criteria already in existence (e.g., professional competence, multinational mix, male–female ratio, etc.). In addition, simulation experience has shown that having couples in a crew does not entirely prevent disruptive jealousies and rivalries from occurring (e.g., the Biosphere 2 project). More work needs to be done in examining the sexual implications of male–female crew composition during a long-duration space expedition, such as a trip to Mars.

10.2 MARS 500 PROJECT

A number of psychosocial issues related to an expedition to Mars were examined during a unique ground-based space simulation project that took place from June 2010 to November 2011 at the Institute for Biomedical Problems in Moscow. Called the Mars 500 Project, it was designed to simulate a 520-day round-trip expedition to Mars. Six men (three Russians, two Europeans, and one Chinese) were confined in a facility where the lower floor consisted of living and laboratory modules and the upper floor contained a mock-up of the Mars surface, on which the crew conducted simulated geological and other planetary activities. The mission included periods of time where the isolated crew functioned under high-autonomy conditions, including communication delays with people working outside in the simulated Mission Control. The results from an earlier pilot study in this facility lasting 105 days were discussed in Sect. 9.3. Here, we will summarize the results from psychosocial studies that took place during the actual mission.

Gushin et al. [3] found changes in crewmember time perception, evidence for the displacement of crew tension to Mission Control, and decreases in crewmember needs and requests during high autonomy, which suggested that the crew had successfully adapted to this condition. Sandal [4] reported that the crew exhibited increased homogeneity in values and reluctance to express negative interpersonal feelings over time, which suggested a tendency toward "groupthink." Van Baarsen et al. found that the crewmembers experienced increased feelings of loneliness and decreased support from colleagues over time, which negatively affected cognitive adaptation [5], and that several factors affected motivation [6]. Basner, Dinges, and their team [7] used wrist actigraphy, the psychomotor vigilance test, and various subjective measures to study the crew and found a number of individual differences in terms of sleep pattern, mood, and conflicts with Mission Control. They did not find any evidence for a third quarter phenomenon in any of their psychological or behavioral measures (see Sect. 2.2). These investigators also found that the majority of crewmembers experienced one or more disturbances of sleep quality or altered sleep–wake periodicity, and there was a tendency for active wakefulness levels to drop throughout the mission until the last 20 days, when they rose in anticipation of the end of the seclusion [8]. Tafforin [9] evaluated video recordings of crew behavior during breakfasts and found variations in personal actions, visual interactions, and facial expressions, but a general decrease in group collective time from the outbound to the return phase of the simulated mission. Finally, Solcova et al. [10] used mood questionnaires and a semi-structured post-mission interview to study affective processes in the crew. They found that the crewmembers reported predominately positive emotions throughout the mission and that changes in mood were asynchronous and balanced. The results suggested that, unlike in everyday life, the crew preferred to express emotions with positive valence, and negative emotions were being suppressed and neutralized.

As an operational demonstration, the Mars 500 Project was very successful in highlighting important issues to be expected on a Mars expedition. In addition, much was learned about how a particular group of men may interact in an isolated and confined setting on Earth for a long period of time. Further long-duration mission simulations need to be done with different crews that also include female members. For a true simulation of a Mars expedition, the International Space Station (ISS) could be used to simulate the microgravity outbound and return phases of the mission, and time spent on the Moon could simulate the partial gravity planet-like condition of an actual landing on Mars.

10.3 DEALING WITH THE PSYCHOSOCIAL ISSUES ON A MARS EXPEDITION

Based on current knowledge, there are several countermeasures that could be implemented to help ameliorate the impact of the above issues on the crew of a Mars expedition. Some of these are natural follow-ups to successful countermeasures used in near-Earth missions (see Chap. 8). Others are prompted by the unique psychosocial stressors inherent in a long interplanetary mission.

Crewmembers should be selected to include people who are psychologically minded and are equally comfortable working alone on a project when necessary as well as

interacting with their teammates and valuing teamwork in general. Commanders should be selected who have a history of using both task and support leadership characteristics in accordance with the needs of their team. They also should be sensitive to the impact of psychological and cultural factors on individual and crew behavior.

Pre launch, crewmembers and Mission Control personnel should receive psychosocial education training aimed at recognizing and dealing with important psychological and interpersonal issues. Some of this training needs to be done conjointly with the crew and key members of the Mission Control staff. Important topic areas include ways to work and interact productively under isolated and confined conditions, recognizing and dealing with potential intrapsychic and interpersonal problems, and coping with increased autonomy and dependence on local resources.

During the mission itself, crewmembers and Mission Control personnel should utilize computer-based self-help and psychosocial education training refresher courses to remind them of key issues discussed prior to launch. Crews should plan time for "bull sessions" to discuss personal and interpersonal issues and stressors before they fester and become problematic. Strategies need to be developed to allow crewmembers to communicate efficiently with people on Earth during time-delayed conditions. For example, e-mail messages could be written that include suggested response choices at the end to which the recipient may reply without the need for repeated back-and-forth communications. Other strategies include greater attention and foresight in the use of longer (and perhaps less frequent) transmissions, and the technical implementation of voice-to-text transcriptions [11]. An on-board telescope with which to see Earth in real time may help the crewmembers deal with feelings around separation from their home planet.

Families at home need to be supported during the mission, using both informal (peer-led groups) and formal (counseling with a therapist) activities. Post-return readaptation debriefings and supportive activities need to be employed to help both the returning astronauts and their families readjust to life on Earth together and deal with the fame and glory resulting from a highly visible space expedition. The first mission to Mars will be a major human accomplishment, with important psychological ramifications for everyone involved, including the general public.

REFERENCES

1. Kanas, N., & Manzey, D. (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA: Microcosm Press.
2. Nechaev, A. P., Polyakov, V. V., & Morukov, B. V. (2007). Martian manned mission: What cosmonauts think about this. *Acta Astronautica, 60*, 351–353.
3. Gushin, V., Shved, D., Ehmann, B., Balazss, L., & Komarevtsev, S. (2012). Crew–MC interactions during communication delay in Mars-500. Paper # IAC-12-A1.1.2. In *Proceedings of the 63rd International Astronautical Congress*, International Astronautical Federation, Naples, Italy, October 1–5, 2012.
4. Sandal, G. M. (2012). "Groupthink" on a mission to Mars: Results from a 520 days space simulation study. Paper # IAC-12-A1.1.3. In *Proceedings of the 63rd International Astronautical Congress*, International Astronautical Federation, Naples, Italy, October 1–5, 2012.
5. Van Baarsen, B., Ferlazzo, F., Ferravante, D., Smit, J., van der Pligt, J., and van Duijn, M. (2012). The effects of extreme isolation on loneliness and cognitive control processes: Analyses of the Lodgead data obtained during the Mars105 and the Mars520 studies. Paper # IAC-12-A1.1.4. In *Proceedings*

of the 63rd International Astronautical Congress, October 1–5, 2012. Naples, Italy: International Astronautical Federation.

6. Van Baarsen, B. (2013). Person autonomy and voluntariness as important factors in motivation, decision making, and astronaut safety: First results from the Mars500 LODGEAD study. *Acta Astronautica, 87*, 139–146.
7. Basner, M., Dinges, D. F., Mollicone, D. J., Savelev, I., Ecker, A. J., Di Antonio, A., et al. (2014). Psychological and behavioral changes during confinement in a 520-day simulated interplanetary mission to Mars. *PLoS ONE, 9*(3), e93298. doi:10.1371/journal.pone.0093298.
8. Basner, M., Dinges, D. F., Mollicone, D., Ecker, A., Jones, C. W., Hyder, E. C., et al. (2013). Mars 520-d mission simulation reveals protracted crew hypokinesis and alterations of sleep duration and timing. *Proceedings of the National Academy of Sciences of the United States of America, 110*(7), 2635–2640.
9. Tafforin, C. (2013). The Mars-500 crew in daily life activities: An ethological study. *Acta Astronautica, 91*, 69–76.
10. Solcova, I. P., Lacev, A., & Solcova, I. (2014). Study of individual and group affective processes in the crew of a simulated mission to Mars: Positive affectivity as a valuable indicator of changes in the crew affectivity. *Acta Astronautica, 100*, 57–67.
11. Love, S. G., & Reagan, M. L. (2013). Delayed voice communication. *Acta Astronautica, 91*, 89–95.

11

Missions to the Outer Solar System

The planets in our Solar System all have been visited by robotic probes, and we now have a good sense of their appearance and composition (Fig. 11.1). As we consider manned missions to planets beyond Mars, the tremendous distances involved necessitate the presence of additional stressors that have major psychological ramifications. But before we deal with them, let's take a look at our Solar System, especially the region beyond Mars (which was considered in the last chapter).

11.1 THE OUTER SOLAR SYSTEM

Our concept of the Solar System has changed dramatically in recent years. With the discovery of Pluto in 1930, it was thought that the outer boundary was set, and the Solar System consisted of the Sun, nine planets and their moons, some asteroids, and an occasional comet that entered our system by chance and was captured by the gravitational pull of the Sun. But by 1960 (see Table 11.1, left column), it became apparent that cometary nuclei actually resided in the flat Kuiper Belt at about the distance of Pluto (short-period comets) and a more distant spherical Oort Cloud that reached about a quarter of the distance to the nearest star beyond the Sun (long-period comets). Both of these areas circle the Sun and are now considered to be part of the Solar System. They differ dramatically in size, as is shown in Fig. 11.2. The composition of the Solar System (but not its size) changed again with the demotion of Pluto from a planet to one of several dwarf planets, and its uniqueness was shattered with the discovery of thousands of exoplanets orbiting distant stars (see Table 11.1, right column).

In terms of distances to the outer Solar System, Table 11.2 shows these, as well as the time it would take to ask a question and receive an answer from Earth (note that A-V transmissions move at the speed of light), and the duration of a manned mission to each body based on current chemical propulsion technology, similar to that being planned for a mission to Mars. Taking another example, consider the Voyager 2 "Grand Tour" mission through the Solar System that was launched on August 20, 1977, taking advantage of a favorable planetary alignment that allowed for gravity assist. It took this space probe just under 2 years to make a one-way trip to Jupiter, 4 years to reach Saturn, nearly 8.5 years to reach Uranus, and 12 years to reach Neptune. Doubling these figures closely

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_11

11.1 A montage of the Solar System planets and our Moon at the end of the twentieth century. The individual body images were taken from probes and powerful telescopes. NASA/ GRIN (Great Images in NASA)/JPL digital image

approximates the round-trip durations listed in the fourth column of Table 11.2. The figures used in the table are averages and include only transit times, not time spent exploring the planet. Even so, the distances and times are enormous

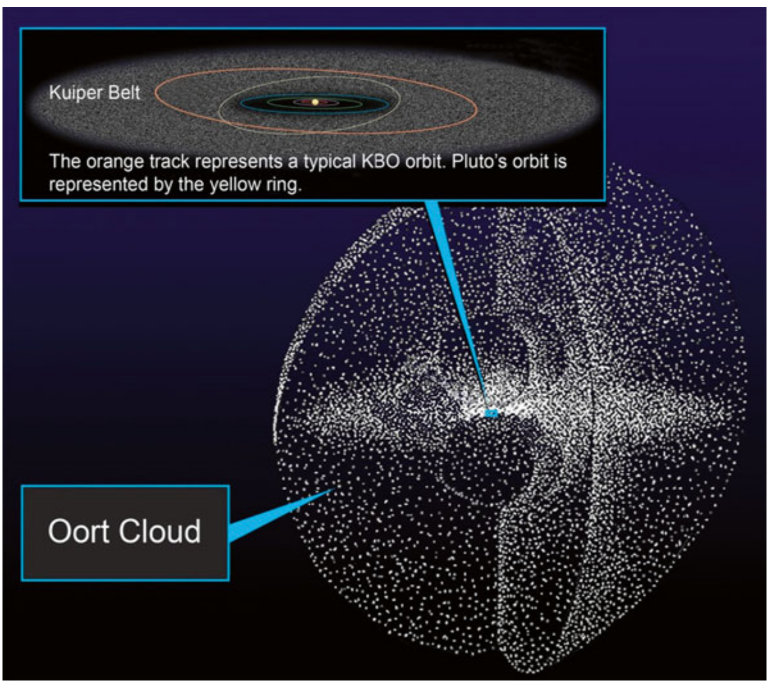
11.2 WHY GO TO THE OUTER SOLAR SYSTEM?

There are several reasons to go on deep-space missions. The first relates to the possibility of finding and studying non-Earth life. We know from orbiting spacecraft and surface probes that Mars currently has frozen water trapped in its polar caps and just below its surface. The Tharsis region is thought to be a volcanic area, and probes have imaged

Table 11.1 Composition of the Solar System

Solar System ca. 1960	Solar System ca. 2014
Sun	Sun
Mercury	Mercury
Venus	Venus
Earth + Moon	Earth + Moon
Mars + moons	Mars + moons
Asteroids (1,800+)	Asteroids (300,000+)
Jupiter + moons	Jupiter + moons
Saturn + moons	Saturn + moons
Uranus + moons	Uranus + moons
Neptune + moons	Neptune + moons
Pluto	Dwarf planets (Pluto, etc.)
Kuiper Belt	Kuiper Belt
Oort Cloud	Oort Cloud
Unbounded moving stars	Unbounded moving stars
Clusters, nebulae, galaxies	Extra-solar planets
	Clusters, nebulae, galaxies

Adapted from *Solar System Maps: From Antiquity to the Space Age*, Nick Kanas, Springer, 2014

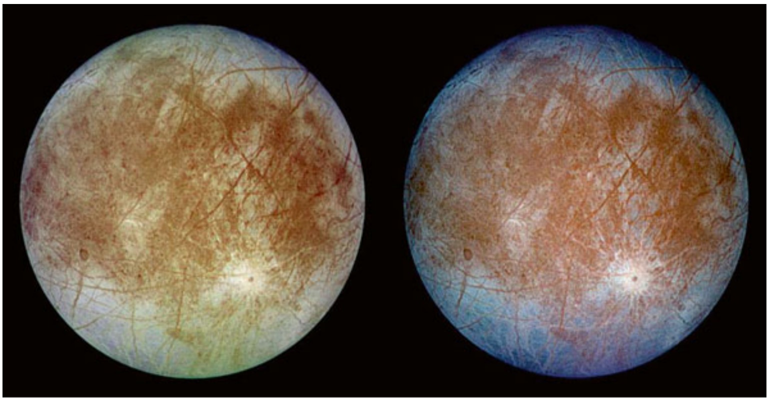


11.2 A comparison between the sizes of the relatively small and flat Kuiper Belt and the huge, spherical Oort Cloud. Note Pluto's orbit embedded in the Kuiper Belt. NASA digital image

Table 11.2 Characteristics of manned missions to the outer Solar System using current technology

	Distance to Earth	Two-way talk time	RT mission duration
Mars	228,000,000 km	25 min (max: 44 min)	1.3 years
Jupiter	778,000,000 km	87 min	4.5 years
Saturn	1,427,000,000 km	159 min	8.3 years
Uranus	2,871,000,000 km	319 min	16.8 years
Neptune	4,498,000,000 km	500 min	26.3 years
Kuiper Belt	5,906,000,000 km	657 min	34.5 years
Oort Cloud	0.63–0.94 light year[a]	1.26–1.88 years	Centuries

[a]1 light year = 9.46 trillion kilometers



11.3 Two images of Jupiter's moon Europa taken by the Galileo spacecraft on September 7, 1996. The image on the left is in natural color, and the image on the right is in false color to enhance surface features. Ice from a presumed subsurface ocean that may harbor life is shown in blue. NASA/NSSDC/JPL digital image

openings suggestive of caves, so it is possible that sheltered hot springs are present inside that contain steam and liquid water. Mars's atmosphere, although thin, contains carbon dioxide and methane, so it is possible that under the right conditions, microorganisms that give off methane could be present. Methanogens exist naturally on Earth [1], and they and other organisms have been grown in the laboratory under partially analogous Mars-like conditions [2–4]. In addition, water and liquid hydrocarbons are thought to exist on some of the moons of the gas giants in our Solar System (Fig. 11.3). Irwin and Schulze-Makuch [5] have suggested that life may form in these environments, such as a watery subsurface on Europa or an aqueous ammonia or liquid ethane habitat on Titan. Comets also contain water, and it is thought that cometary collisions with planetary bodies may be one way that water accumulates on their surfaces. It has even been proposed that life may exist in the cometary nuclei occupying the Kepler Belt [6]. We know that bacteria exist on Earth in very inhospitable conditions involving high or low temperatures, highly acidic or alkaline conditions, high or low pressures, and even high radiation. These extremophiles have been found under the Antarctic ice, around volcanic vents and hot springs, and attached to

rocks. Finally, living bacterial spores have been retrieved from orbiting satellites, where they spent more than five years basking in ultraviolet light and a deep vacuum. Bacteria are very hardy microorganisms indeed! So, who knows, we may find microorganisms on distant Solar System bodies as well.

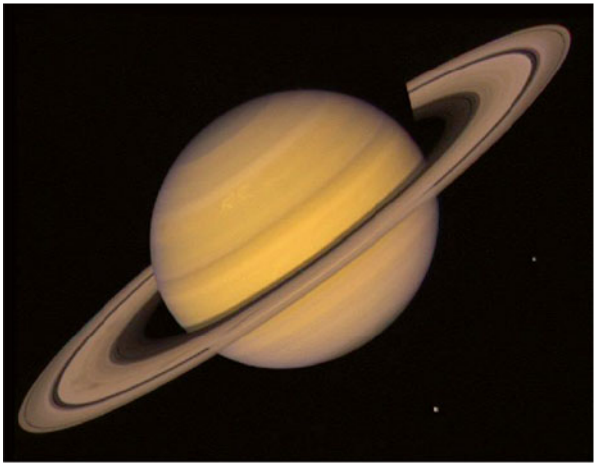
There are other reasons why we might want to travel to the outer Solar System. Should Earth become inhospitable due to negative climate change or overpopulation, we may be able to form colonies on Mars or on some of the moons of the distant gas giant planets. In addition, by exploring the unknown, we keep ourselves vibrant—an essential feature to keep a civilization from stagnating [7]. Finally, there may be economic advantages of trade and mining activities involving distant mineral-rich planetary bodies. For example, as we shall see below, pellets of helium-3 and deuterium have been proposed as fuel for advanced fusion-powered propulsion systems for deep-space travel. Since helium-3 is rare on Earth, it would have to be mined elsewhere, such as the atmosphere of Jupiter or Saturn, possibly using robotic helium mines suspended by balloons [8, 9]. It has been suggested that deuterium could be obtained in large quantities from cometary nuclei in the Oort Cloud [10].

Many of the same psychological and interpersonal stressors discussed in the previous chapter for a Mars expedition continue to be relevant for missions to the outer Solar System (e.g., isolation from Earth, periods of monotony, increased crewmember autonomy, reliance on on-board resources, "Earth-out-of-view phenomenon," etc.). Consider a round-trip mission to Uranus. The two-way communication time of 5.3 h would make real-time discussions with Mission Control or family and friends on Earth realistically impossible, and this would accentuate the isolation and loneliness felt by the crewmembers. Earth likely would disappear from view unless visualized through a telescope, adding to the sense of isolation. In addition, what would one do to occupy time during the nearly 17-year round-trip mission? How would the crewmembers get along with each other during this time? A 45-year-old astronaut undertaking this mission would be approaching retirement age upon returning, with children having grown up and perhaps having children of their own. In addition, family members and friends would have aged, and some will have died in the interval. These factors would create a selection problem for the crew—what kind of people would want to go on such a mission? Time and aging effects also would increase the chances of crewmembers developing a medical or psychiatric illness.

It is hard to imagine that such missions to the outer planets would occur under current methods of travel, and new concepts likely would be employed, such as velocities representing a significant fraction of the speed of light and suspended animation. Both of these issues now will be discussed.

11.3 RAPID PROPULSION SYSTEMS

In order to go to the outer planets or to places like the Kuiper Belt (where Pluto resides) or the Oort Cloud in a reasonable amount of time, new propulsion systems will need to be developed to allow accelerations up to a significant fraction of the speed of light. Although relativistic effects such as time dilation are important close to light speed, they are relatively negligible at speeds in the range of 10 % that of light (written as .10c). If a space



11.4 Image of Saturn taken by Voyager 2 on July 21, 1981. Deuterium and helium-3 have been proposed as fuel for advanced fusion-powered propulsion systems for deep-space travel. Helium-3 is rare on Earth, so it would have to be mined elsewhere. One possibility would be in the atmosphere of Jupiter or Saturn, possibly using robotic helium mines suspended by balloons. NASA/NSSDC/JPL digital image

ship averaged this speed for its entire mission, it would take only a little over a day to reach Uranus, making such a trip not much longer than an airline trip from New York to Shanghai.

Three kinds of propulsion system have been identified for missions to the outer Solar System (as well as to nearby stars) [11]. One type carries its own fuel. Examples include the nuclear fission rocket, which uses a nuclear reactor to thermally accelerate hydrogen atoms to provide thrust; the nuclear pulse rocket, which is propelled by small nuclear bombs ejected and exploded every few seconds or so against a heavy-duty pusher plate at the back; a fusion-powered rocket, where pellets of deuterium and helium-3 collected from our gas giant planets (Fig. 11.4) are compressed and heated in a combustion chamber inside the ship by high-energy electron beams or lasers; and rockets using the reaction of matter and antimatter to provide the energy that moves the vehicle.

A second propulsion system is a hybrid that relies on external energy sources, thus decreasing the amount of mass that must be carried on board, but which uses small amounts of internally supplied energy to activate the system. One such example is the Bussard interstellar ramjet, which consists of a fusion reactor and a large electrical or magnetic scoop to collect onrushing charged particles from space along the flight path. Interstellar hydrogen is the main fuel source, although some supplemental intrinsic fuel is necessary to fire up the system and for travel through low-hydrogen areas. A variant of the Bussard approach is the Ram-augmented Interstellar Rocket (RAIR), which incorporates a separate fusion reaction that uses a small amount of intrinsic fuel such as deuterium and helium-3. In this case, the reaction serves to energize the hydrogen that is collected from space by a ramscoop, and the hydrogen is not used as fuel, but as reaction mass to produce thrust for the starship.

A final propulsion system only uses external energy sources to move the vehicle. The type usually mentioned employs the momentum of light photons from the Sun to "push" against a solar sail, thus moving the vehicle in the direction of the beam. Other beam/sail systems have been suggested as well, such as using small charged pellets accelerated by an electromagnetic mass driver which strike a magnetic field sail, or lasers aimed by a Fresnel lens reflecting against a large light sail.

Several of these propulsion systems are capable of achieving very high speeds that would cut down on travel time, but they present difficult technological and engineering problems. In addition, the rapidly oncoming flow of interstellar gas, dust particles, and cosmic rays on the space ship and its inhabitants could present unique particulate and radiation hazards [12]. Some kind of deflector shield and laser combination in the front will be necessary to block oncoming gas and dust particles and vaporize larger bodies. To protect against oncoming cosmic rays, a passive rock or metal shield or an active magnetic or electric field deflector could be used [13].

At the present time, these systems are still in development. But, assuming that such means of propulsion could be utilized, it is difficult to predict their effects on human psychology. For example, consider the anxiety that might result from flying to Uranus on a manned space vehicle that explodes nuclear bomblets every few seconds against a pusher plate located at the back of the vehicle! But in time, as the technology is tested and developed, the psychological concerns likely will decrease to the levels currently experienced today using chemical systems.

11.4 SUSPENDED ANIMATION

A second technological aid for travel to the extreme reaches of the Solar System is to put the crew in suspended animation during much of the mission. For example, traveling at an average speed of .10c to the middle of the Oort Cloud to mine cometary nuclei would represent a one-way trip of nearly 8 years. It would decrease the use of consumables and cut down on monotony and boredom if the crew could spend much of this time in suspended animation. In this scenario, after the critical activities involving the launch have been accomplished, the crewmembers would be put in a state where their physiological functions are slowed down until such time as they are near their destination, when they would be "awakened" to perform their landing and exploration duties. This notion proposes the effective cessation of metabolism in the crewmembers due to drugs and/or extreme cold (i.e., cryosleep). The spaceship would be on autopilot during the bulk of the mission, and computers would handle life support and navigation, as well as the revival process.

Although popular in science fiction [11], suspended animation is not a trivial matter. The problem is that the technology to put an entire human being in this state has yet to be developed, and the process is fraught with difficulties. Although freezing is used today to preserve red blood cells and corneas for transplantation, Freezing and later thawing complete organ systems and whole bodies composed of differentiated cells with different freeze–thaw rate profiles is beyond our abilities in the foreseeable future [9, 11, 13, 14]. Ice crystals can form, which can be lethal to cells, and areas of the body can be deprived

of oxygen and die from blood clotting or premature freezing before metabolism is slowed down. The thawing of previously frozen cells and tissues presents risks of ice crystal formation and damage as well.

But even if suspended animation becomes technically possible, problems could still occur. Perhaps there are unknown physical and physiological effects of long-term suspended animation that might result in permanent organ damage or impaired brain function. Other risks include power surges or breakdowns of the life-sustaining equipment during the long period of time of the journey. In addition, psychological problems could occur prior to freezing in people fearful of being incapacitated for years at a time or worrying that some threat could occur, such as a collision with a meteoroid or equipment failure. Computers and collision detectors likely would be employed, but such machines are not perfect. The notion of being helplessly dependent on them to maintain and revive the crew is not a comfortable thought and could create anxiety and stress reactions. Many people would prefer to be awake for the number of years it would take to reach their destination in the outer Solar System.

REFERENCES

1. Methane found in desert soils bolsters theories that life could exist on Mars. *ScienceDaily*. Retrieved November 8, 2005, from www.sciencedaily.com/releases/2005/11/051107083842.htm
2. Diaz, B., & Schulze-Makuch, D. (2006). Microbial survival rates of *Escherichia coli* and *Deinococcus radiodurans* under low temperature, low pressure, and UV-irradiation conditions, and their relevance to possible Martian life. *Astrobiology, 6*(2), 332–347.
3. Model methanogens provide clues to possible Mars life. *ScienceDaily.* Retrieved May 28, 2007, from www.sciencedaily.com/releases/2007/05/070525204839.htm
4. De Vera, J.-P. P., Schulze-Makuch, D., Khan, A., Lorek, A., Koncz, A., Mohlmann, D., et al. (2012). The adaptation potential of extremophiles to Martian surface conditions and its implication for the habitability of Mars. *Geophysical Research Abstracts, 14*, EGU2012–EGU2113.
5. Irwin, L. N., & Schulze-Makuch, D. (2003). *Cosmic biology: How life could evolve on other worlds*. New York: Springer Science+Business Media.
6. Dyson, F. J. (2003). Looking for life in unlikely places. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, ON: Apogee Books.
7. Kondo, Y. (2003). Interstellar travel and multi-generation space ships: An overview. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, ON: Apogee Books.
8. Matloff, G. (2012). Fusion starships. In L. Johnson & J. McDevitt (Eds.), *Going interstellar*. Riversdale, NY: Baen.
9. Matloff, G. L. (2005). *Deep space probes: To the outer solar system and beyond* (2nd ed.). New York: Springer Science+Business Media.
10. Winterberg, F. (2009). Advanced deuterium fusion rocket propulsion for manned deep space missions. *Journal of the British Interplanetary Society, 62*, 386–401.
11. Kanas, N. (2014). *The protos mandate: A scientific novel (Part II: The science behind the fiction)*. New York: Springer Science+Business Media.
12. Semyonov, O. G. (2009). Radiation hazard of relativistic interstellar flight. *Acta Astronautica, 64*, 644–653.
13. Mallove, E. F., & Matloff, G. L. (1989). *The starflight handbook: A Pioneer's guide to interstellar Travel*. New York: Wiley.
14. Stratmann, H. (2015). Suspended animation: Putting characters on ice. In *Using Medicine in Science Fiction*. New York: Springer Science+Business Media.

12

Interstellar Missions

When considering interstellar missions, distance again is a major factor. Whereas the outer boundary of our Solar System at the far edge, the Oort Cloud, is less than one light year from us, the closest star is over four times away. In our Sun's neighborhood, the closest stars and their distances in light years (in parentheses) are: Proxima Centauri (4.2), Alpha Centauri A and B (4.4), Barnard's Star (5.9), Wolf 359 (7.8), Lalande 21185 (8.3), Sirius A and B (8.6), UV Ceti A and B (8.7), Ross 154 (9.7), Ross 248 (10.3), and Epsilon Eridani (10.5). All of these distances are a long way away: trillions of kilometers! Using current technology, interstellar travel is highly unlikely. For example, a starship traveling at the same speed as Voyager 2 would take around 497,000 years to reach the Sirius star system [1]. Consequently, some sort of advanced propulsion system, such as was discussed in the previous chapter, would be needed. Such a starship moving at an average of 10 % the speed of light (.10c) would take 86 years to reach Sirius.

Interstellar travel times like this would be longer than the expected lifetime of most of the crewmembers and would necessitate a multigenerational approach. This means that most of the crewmembers who start the mission would not be alive to see it end (unless they were placed in suspended animation—see Chap. 11). Since most of the crewmembers arriving at the distant star would not have been born at the time of launch, Earth would only be something they learned about in their history classes and not something they experienced directly. These factors introduce a number of new psychological and sociological stressors, which will be discussed later. But first let us consider some of the practical issues involved with an interstellar mission.

12.1 FEASIBILITY OF AN INTERSTELLAR MISSION

The technology to propel and protect a starship would be enormously complicated and expensive, especially when one considers the massive size of the ship itself. Consider the scenario of a huge, self-contained multigenerational starship full of colonists needing to be kept alive for decades while traveling to a distant star. Strong [2] has envisioned giant 100-megaton starships containing 100–150 people that would be equipped for century-long journeys to the stars. Woodcock [3] imagines even larger one million metric ton

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_12

starships the length of 11 football fields that would carry 10,000 people. We looked at the need for new propulsion systems for deep-space vehicles in Chap. 11. Let's examine some of the other factors related to an interstellar mission.

Zubrin [4] has examined the economics of a starship with a dry mass of 1,000 "tons" that can cruise at .10c and carry a few score colonists on a trip lasting several decades. He estimates that if this ship operates at an unlikely 100 % efficiency, the energy costs alone would amount to US$12.5 trillion. The addition of other costs, such as technology development and hardware manufacture, raises the price tag to US$125 trillion! This is roughly 1,000 times the cost of the Apollo program in today's dollars. He estimates that a future spacefaring civilization will need a GDP 200 times greater than today and a total human population of some 40 billion to make this possible.

In order to commit these kinds of resources, there needs to be great motivation to counter competing social priorities. Perhaps negative climate change sequelae from global warming will provide enough incentive [5]. But other factors likely will need to come into play, such as overpopulation that can't be absorbed by space stations and colonies on planets in our Solar System; the search for extrasolar life; scientific advancements; and economic profit incentives (e.g., mining distant planetary bodies). Technological breakthroughs will be necessary, such as developing an efficient fusion reactor. But due to the scale and economics of the situation, a fusion propulsion system may not be used for the colony ship. Instead, beamed propulsion might be adequate, although interstellar travel by this method would be slow and require much more time to reach the destination stars.

In terms of where to go, suitable candidates include nearby stars with extrasolar planets. It has become apparent that exoplanets orbiting stars other than our own are quite common in the universe (and in fact have been speculated upon for centuries—see Fig. 12.1). The Kepler Space Telescope, launched on March 6, 2009, has been quite successful in discovering such objects in space. Thanks to the performance of this remarkable instrument, the NASA Exoplanet Archive [6], on February 5, 2015, listed 1,813 confirmed exoplanets and 462 multi-planet star systems. More exoplanets continue to be listed weekly as data are processed by the Kepler instrument (Fig. 12.2). In addition, many of these planets are in the star's so-called habitable (or "Goldilocks") zone: not too hot or too cold, but at the right distance to have surface temperatures conducive to liquid water, thus making them possible candidates for life. A recent study found 10 Earth-sized exoplanets orbiting in their respective star's habitable zone [7]. This same study concluded that 22 % of Sun-like stars in our galaxy may harbor Earth-sized planets that orbit in their habitable zones, and that the nearest such planet may well be within 12 light years from us. Nineteen single or double star systems lie within this distance [8, 9].

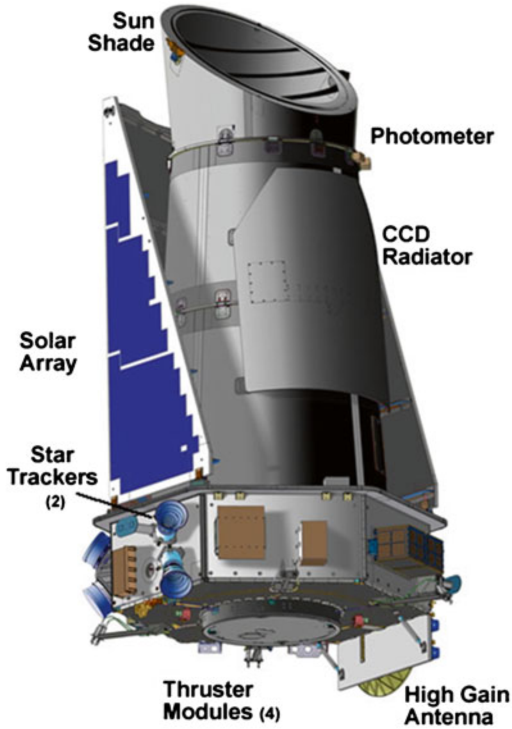
Three of these systems are thought to have at least one planet orbiting a star [10]. In November 2012, an Earth-like star was thought to have been detected around Alpha Centauri B, located 4.4 light years from us. If confirmed, the planet likely would be very close to its star, and therefore too hot to be habitable [11]. Work published in December 2012 has suggested that the Sun-like star Tau Ceti, located 11.9 light years away, may host a system of up to five planets ranging in size from two to seven Earth masses, and that two of these are close to the star's habitable zone [11].

A bit closer to us at 10.5 light years away, and better studied than the other two star systems, is the interesting system around Epsilon Eridani. With an apparent magnitude of

12.1 Copper engraving from Nicolas *Bion's L'Usage des Globes Celestes et Terrestres…*, which was published in Amsterdam and bound into the 1700 edition of Nicolas Sanson's *Description de tout l' Univers en Plusieurs Cartes*. Note the retinue of planets surrounding distant stars according to the cosmology of Descartes. Courtesy of the Nick and Carolynn Kanas Collection; and *Solar System Maps: From Antiquity to the Space Age*, Nick Kanas, Springer/Praxis, 2014

3.7, this young orange star likely is less than a billion years old and has a mass of about 80 % that of our Sun [12–15]. A number of components are thought to surround the star, including an inner asteroid belt, a large planet that is around 1.5 times the mass of Jupiter, an outer asteroid belt, an Earth-sized planet about 10 % the mass of Jupiter, and a Kuiper belt-like dust disk [12, 16–21]. Perhaps other planets exist in the system, especially bordering and helping to form the belts and disk.

Young K2 stars like Epsilon Eridani are seen as good possibilities to harbor planets that support life. This is because they are numerous in number, are stable for long periods of time, and potential planets orbiting them are less likely to be trapped in a synchronous rotation due to tidal damping than planets around older stars [12, 22–24]. Recently, the



12.2 The Kepler telescope was launched for the purpose of detecting exoplanets around stars, especially those approximating the size of Earth and located in the star's habitable zone. The telescope has been very successful in finding new exoplanets despite some recent problems with its gyroscopes. NASA/Ames Research Center image

Kepler telescope discovered two Earth-sized planets orbiting another K2 star (Kepler-62) that is two-thirds the size of our Sun but is located 1,200 light years away from us—too distant for an early interstellar mission (unless we somehow figure out a way of exceeding the speed of light or traveling through "worm holes" in space—speculative ideas that are part of the science-fiction genre).

In time, it is likely that exoplanets will be found relatively close to us that are good candidates for colonization (Fig. 12.3). If so, what would such a colony be like? Based on his analyses of 13 post-migration communities on Earth, Schwartz [25] has conceptualized three typical stages of organization following an interstellar migration. The first is the pioneering phase, lasting 2–4 years, where the new settlement may experience tension and factionalism over issues related to physical survival. After food has been provided in a reliable manner, and after permanent shelters have been established, the community may enter into the consolidation phase, where it crystallizes and formalizes its social institutions and associations, and a sense of group solidarity begins to develop. As the potential factionalism of the first two stages is dealt with, and ways of resolving disagreements are established, the community enters into the third phase—stabilization—where it continues to develop in ways not directly related to the resettlement.

12.3 Frontispiece from the 1742 edition of Doppelmayr's *Atlas Coelestis*. Note at the top a depiction of our Solar System surrounded by nearby star systems with their own retinue of planets. Below are images of famous astronomers of the past. Courtesy of the Nick and Carolynn Kanas Collection; and *Solar System Maps: From Antiquity to the Space Age*, Nick Kanas, Springer/Praxis, 2014

In terms of religion, Schwartz [25] outlines three patterns: a simplification of the religious system in the early years following the migration; a rise in its importance as a factor increasing the unity of the community; or as a vehicle for factionalism after the initial period of settlement. How these factors will apply to a new interstellar community is dependent upon the specific conditions and social conventions of the group.

Besides colonization, the settler likely will spend time looking for native life. After all, the exoplanet selected for human habitation will have a number of Earth-like characteristics with respect to gravity, a rocky surface, moderate temperatures, tolerable radiation, an atmosphere with oxygen, liquid water, and plant-producing soil [26, 27]. As a result, any life that is discovered likely will be carbon-based and require sunlight and water. On Earth, there are a number of extremophilic microorganisms that survive under inhospitable conditions of temperature, radiation, acidity/alkalinity, and pressure [27]. Irwin and Schulze-Makuch [17] have made a good case for life forming in exotic environments such as a watery subsurface on Europa or in aqueous ammonia or liquid ethane habitats on Titan. So it is anybody's guess as to what kinds of alien life future colonists will have to deal with. The likeliest possibility is some type of microorganism, but perhaps a life form similar to slime molds on Earth [28] or perhaps an even more evolved plant or animal organism will be found. This will have important psychological ramifications, as we will now consider.

12.2 PSYCHOLOGICAL AND SOCIOLOGICAL ISSUES OF AN INTERSTELLAR MISSION

Multigenerational interstellar missions lasting decades or centuries will be affected by many of the psychological and interpersonal stressors considered in previous chapters. But these will take on new dimensions due to the presence of several generations on board the starship. In addition, the size and heterogeneity of the crew will introduce new sociological problems [29] and important psychosocial stressors such as:

- selection issues: Who will want to go? Who will be excluded?
- feelings of isolation and loneliness in deep space;
- disappearing Earth and Solar System: the Sun as an insignificant star;
- lack of novelty and social contacts in deep space;
- dealing with monotony and leisure time;
- complete autonomy and greatly delayed communication with Earth;
- dealing with mentally or medically ill people in a confined space;
- unknown physical and psychological effects of near-relativistic speed;
- starship environment: sustainable resources, gravity, population control;
- intolerance of diversity: cultural factors, religion, language differences;
- homesickness, especially the first generation who remember Earth;
- dealing with myths and folklore regarding Earth in later generations;
- keeping the original mission goals: rebellion by later generations;
- dealing with criminals and sociopaths in a relatively small social network;
- psychological and ethical effects of social engineering: coupling, birth rate;
- impact of discovering native life at the destination site.

First and foremost is the selection of the crewmember colonists. Who would volunteer to undergo on such a mission, where many family members and friends will be left behind on Earth and not be seen again? How will the crewmember selection be made? Will it be based on lottery, mission skills, genetic make-up, or politics? In terms of family members, who will be allowed to go and who will be excluded? After all, food, water, space, and atmospheric resources will be limited, and the presence of a child or unskilled family member could take the place of another crewmember who might be a more productive member of the society. Finally, since a future colony should have some diversity, what would be the optimal mix in initial crew selection in terms of male–female ratio, race, nationality, religion, occupation, intelligence, etc.? These are all important issues that may affect crew cohesion and the ultimate success of the mission.

Once underway, the crewmembers of a starship will experience a sense of isolation and separation from Earth and all its personal associations. Contributing to this will be the experience of seeing not only Earth retreat then disappear from sight, but also our Solar System. Even the Sun will become an insignificant star in the heavens (Fig. 12.4). Will this

12.4 A galaxy (NGC4414), as seen through the Hubble Space Telescope. Spiral galaxies like this one are composed of around 100 billion stars. Our Sun is just one such star located on the periphery of a spiral arm of the Milky Way Galaxy. How will future astronauts take to the fact that their home planet and star are insignificant as they travel to other stars? Courtesy of NASA/GRIN (Great Images in NASA); and *Star Maps: History, Artistry, and Cartography*, 2nd ed., Nick Kanas, Springer/Praxis, 2012

result in profound feelings of loneliness and homesickness? Direct human contact will be limited to just the crewmembers, and ennui may result from the lack of novelty and the predictability of interacting with the same people for years. This will make work and leisure time activities important in order to counteract monotony, and careful attention will need to be paid to having a stimulating habitability design and a wide range of supplies and resources to support hobbies and free time [30]. Starship crewmembers will become completely autonomous from Earth. Long delays will occur in communicating with home, measured in terms of years or even decades, unless some sort of faster-than-light communication system is developed, such as using quantum entanglement [31]. Crewmembers will have to depend upon themselves and on-board computers and machinery for basic life support and operational issues, which may present psychological concerns about hardware and software reliability. The crew also will need to deal directly with all problems and emergencies, such as might be produced by a psychiatrically disturbed crewmember or by a medical problem that affects general crew health. In addition, the physical and psychological effects of radiation may become a factor over time in deep space. This impact may be enhanced as the ship accelerates to a significant proportion of light speed, thus producing an oncoming intense flow of interstellar particles and cosmic rays [32], analogous to driving fast in a snowstorm on Earth.

A number of stressors will arise that are related to the unique environment of living on a starship. Equipment and supplies must be sustainable and recyclable, and the crew will need to be able to maintain and even alter the environment to meet changing needs [33, 34]. Water, food, and medications will need to be produced on board, and advanced technologies using hydroponics, light, genetic engineering, and smart microfarming techniques employing algae may be implemented [35]. For a long multigenerational mission, artificial gravity approximating that of Earth will be necessary. This could be produced by spinning the ship around its longitudinal axis (provided it is wide enough so that Coriolis forces would be minimized) or housing the crew in a wheel habitat revolving around the central core of the starship [33]. The birth rate will need to be controlled to accommodate the available space and resources and to account for unexpected deaths due to illness, epidemics, or starship accidents.

Sociologically, issues related to the crew composition will be important. How much cultural and religious diversity will be tolerated? Will people in the minority be scapegoated during stressful times? Will subgroups emerge that will threaten crew cohesion? How will the social and governance structure deal with these issues? Although a common language is likely to be used, would alternatives be acceptable? What about changes that occur from one generation to another? For example, new vocabulary words relevant for interstellar travel probably will be added to the on-board language, and some "Earth-based" words that are irrelevant might disappear (such as "snow" or "boat") [36].

What about cross-generational issues? The original crewmembers would vividly remember Earth and the family and friends they left behind. This might produce strong feelings of homesickness in this group. Later generations would be less affected by these stressors, since their total existence and reference point will be the multigenerational starship itself. Nevertheless, images and stories of Earth likely will be preserved and become the subject of folklore and longings as time goes on. Some of these stories will take on a mythical quality, distorting what really happened and perhaps creating conflict between

the generations. Another generational difference might result from the need of the first generation to be true to the original goals and objectives of the mission, whereas members of later generations might want to be more flexible in accordance with changing conditions. Some of the latter might even rebel and want to return to Earth. Alternatively, they might want to avoid landing on the targeted exoplanet, preferring to keep going as a permanent spacefaring people without achieving any landfall. If there is a rebellion, how will the rebels be dealt with? Will there be a jail for criminals and sociopaths? What sort of legal system will there be, and how will law-breaking be enforced?

A multigenerational interstellar mission raises important moral and ethical issues [37]. For example, the ethics of applying social engineering principles to keep the population size under control may be questioned. Will men and women pair off into stable couples, or will a more sexually free society evolve? What will be done as regards the practical need for birth control versus the emotional desire of couples to procreate (or perhaps not procreate)? How will the society accommodate people with strong religious views about birth control? When will people be allowed to have children, and how many? How will children be raised: in traditional family units or communally? Some of these notions have been considered in science-fiction stories and novels, sometimes very creatively [5, 28].

Using computer modeling techniques, Moore [38] has discussed some of these ideas about population control in a hypothetical multigenerational starship crew of 150–180 people on a 200-year mission to Alpha Centauri. His work enumerated several social engineering principles that would establish a stable population and maximize the group's productivity. He favors the traditional kinship family organization. However, he would begin the mission with a crew that included a number of young, childless, heterosexual married couples who would agree to postpone parenthood until late in a woman's reproductive life, say in her 30s. This would result in smaller sibships that would require less time for childrearing and free up more time to accomplish mission tasks. Over time, well-defined demographic groups would result, with people of roughly the same age clustered into discrete echelons. The oldest group would be the experts as well as the teachers and babysitters of the youngest echelon. The middle group would be responsible for day-to-day mission operations and tasks relevant to the maintenance of the society.

Although this system has a number of positive demographic advantages, O'Rourke [39] has reminded us that advanced parental age correlates with a higher frequency of unfortunate genetic problems in offspring, such as Down's syndrome and achondroplasia. He also reminds us that in small closed populations, genetic drift can lead to less heterozygosity (i.e., gene variation at the allele level), which can result in the expression of recessive phenotypic traits that might be harmful to offspring. Consequently, vigorous genetic testing and prenatal medical care are givens in such a society. In addition, it is possible that the citizens will not accept such social engineering, especially those of later generations who were born into a system that was not of their choosing. Will they protest and choose to have more children at an earlier age? One can imagine this becoming an issue of rebellion by teenagers and young adults determined to establish more control over their reproductive lives.

Once the targeted exoplanet is reached, what if life is found? The presence of native life will have a profound psychological effect on the colonists, not only as an illustration that humanity is not alone in the universe, but also as something to integrate into their

planning. For example, such life could be seen as a source of food or building material, much as plant life on Earth. Or perhaps the life form would be toxic or dangerous, making it something to be avoided. More advanced life forms could be integrated into the colony as pets, colleagues, or even teachers to learn from. Such life forms could pose a threat if they are not friendly or resent the intrusion of our species onto their home turf, and this circumstance might threaten the very existence of the colony.

In addition, how would news of discovering life that developed around a distant star be met with by people back on Earth after they hear about it some years later? Would this news encourage more support for future interstellar missions, or would it discourage such missions due to religious reasons or a xenophobic fear that our species might be impacted negatively by disease or conquest resulting from such contact in the future. There is no question that the discovery of life on a planet revolving around another star would affect humanity in a profound manner, especially if this life is intelligent. Given the countless number of stars in the universe, life around one star implies that there is life around many others. This realization would change the way we view ourselves and the way we interact with the universe significantly, perhaps more than any other discovery made by our species.

REFERENCES

1. Sheffield, C. (2003). Fly me to the stars: Interstellar travel in fact and fiction. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, Ontario, Canada: Apogee Books.
2. Strong, J. (1965). *Flight to the stars*. New York: Hart.
3. Woodcock, G. R. (1996). To the stars! In S. Schmidt & R. Zubrin (Eds.), *Islands in the sky: Bold new ideas for colonizing space*. New York: Wiley.
4. Zubrin, R. (2013). On the way to starflight: The economics of interstellar breakout. In J. Benford & G. Benford (Eds.), *Starship century: Toward the grandest horizon*. Charleston, SC: Microwave Sciences and Lucky Bat Books.
5. Kanas, N. (2014). *The protos mandate: A scientific novel (Part I: The Novel)*. New York: Springer Science+Business Media.
6. NASA Exoplanet Archive, http://exoplanetarchive.ipac.caltech.edu/index.html.
7. Petigura, E. A., Howard, A. W., & Marcy, G. W. (2013). Prevalence of Earth-size planets orbiting Sun-like stars. *Proceedings of the National Academy of Sciences, 110*(45), 1–6. www.pnas.org/content/early/2013/10/31/1319909110.
8. Crawford, I. A. (2010). Project Icarus: Astronomical considerations relating to the choice of target star. *Journal of the British Interplanetary Society, 63*, 419–425.
9. Obousy, R. K., Tziolas, A. C., Long, K. F., Galea, P., Crowl, A., Crawford, L. A., et al. (2011). Project Icarus: Progress report on technical developments and design considerations. *Journal of the British Interplanetary Society, 64*, 358–371.
10. Matloff, G. L. (2005). *Deep space probes: To the outer solar system and beyond* (2nd ed.). New York: Springer Science+Business Media.
11. Baxter, S., & Crawford, I. (2013). Starship destinations. In J. Benford & G. Benford (Eds.), *Starship century: Toward the grandest horizon*. Charleston, SC: Microwave Sciences and Lucky Bat Books.
12. Wikipedia: Epsilon Eridani, http://en.wikipedia.org/wiki/Epsilon_Eridani.
13. Butler, R. P., Wright, J. T., Marcy, G. W., et al. (2006). Catalog of nearby exoplanets. *Astrophysical Journal, 646*, 505–522. doi:10.1086/504701.
14. Baines, E. K., & Armstrong, J. T. (2011). Confirming fundamental parameters of the exoplanet host star Epsilon Eridani using the Navy Optical Interferometer. *Astrophysical Journal*, arXiv:1112.0447.

15. Drake, J. J., & Smith, G. (1993). The fundamental parameters of the chromospherically active K2 dwarf Epsilon Eridani. *Astrophysical Journal, Part 1, 412*(2), 797–809. doi:10.1086/172962.
16. Clavin, W. (2008). Closest planetary system hosts two asteroid belts, www.nasa.gov/mission_pages/spitzer/news/spitzer-20081027.html.
17. Irwin, L. N., & Schulze-Makuch, D. (2011). *Cosmic biology: How life could evolve on other worlds*. New York: Springer Science+Business Media.
18. Greaves, J. S., Holland, W. S., Moriarty-Schieven, G., et al. (1998). A dust ring around Epsilon Eridani: Analog to the young solar system. *Astrophysical Journal, 506*(2), L133–L137. doi:10.1086/311652.
19. Coulson, I. M., Dent, W. R. F., & Greaves, J. S. (2004). The absence of CO from the dust peak around e Eri. *Monthly Notices of the Royal Astronomical Society, 348*(3), L39–L42. doi:10.1111/j.1365-2966.2004.07563.x.
20. Backman, D., Marengo, M., Stapelfeldt, K., et al. (2008). Epsilon Eridani's planetary debris disk: Structure and dynamics based on Spitzer and CSO observations. *Astrophysical Journal, 690*(2), 1522–1538. doi:10.1088/0004-637X/690/2/1522.
21. Crawford, I. A. (2014). Scientific and societal benefits of interstellar exploration. In K. F. Long (Ed.), *Beyond the boundary: Exploring the science and culture of interstellar spaceflight*. London: Initiative for Interstellar Studies (Chapter 1).
22. Wikipedia: Habitability of orange dwarf systems, http://en.wikipedia.org/wiki/Hability_of_orange_dwarf_systems.
23. Kasting, J. F., Whitmire, D. P., & Reynolds, R. T. (1993). Habitable zones around main sequence stars. *Icarus, 101*, 108–128.
24. Gilster, P. (2009). In praise of K-class stars. *Centauri Dreams*, August 12, 2009, www.centauri-dreams.org/?p=9032.
25. Schwartz, D. W. (1985). The colonizing experience: A cross-cultural perspective. In B. R. Finney & E. M. Jones (Eds.), *Interstellar migration and the human experience*. Berkeley and Los Angeles, CA: University of California Press.
26. Horner, J. (2011). Which exo-Earths should we search for life? *Astronomy & Geophysics, 52*(1), 16–20.
27. Dartnell, L. (2011). Biological constraints on habitability. *Astronomy & Geophysics, 52*(1), 25–28.
28. Kanas, N. (2014). *The protos mandate: A scientific novel (Part II—The science behind the fiction)*. New York: Springer Science+Business Media.
29. Kanas, N. (2011). From Earth's orbit to the outer planets and beyond: Psychological issues in space. *Acta Astronautica, 68*, 576–581.
30. Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation: Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262–276.
31. Fields, D. E. (2014). Starship communication via quantum entanglement. In K. F. Long (Ed.), *Beyond the boundary: Exploring the science and culture of interstellar spaceflight*. London: Initiative for Interstellar Studies (Chapter 14).
32. Semyonov, O. G. (2009). Radiation hazard of relativistic interstellar flight. *Acta Astronautica, 64*, 644–653.
33. Cohen, M. M., Becker, R. E., O'Donnell, D. J., & Brody, A. R. (2013). Interstellar sweat equity. *Journal of the British Interplanetary Society, 66*, 110–124.
34. Ashworth, S. (2012). The emergence of the worldship (II): A development scenario. *Journal of the British Interplanetary Society, 65*, 155–175.
35. Edwards, M. R. (2013). Sustainable functional foods and medicines support vitality, sex, and longevity for a 100-year starship expedition. *Journal of the British Interplanetary Society, 66*, 125–132.
36. Thomason, S. G. (2003). Language change and cultural continuity on multi-generational space ships. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, Ontario, Canada: Apogee Books.

37. Regis, E., Jr. (1985). The moral status of multigenerational interstellar exploration. In B. R. Finney & E. M. Jones (Eds.), *Interstellar migration and the human experience*. Berkeley and Los Angeles, CA: University of California Press.
38. Moore, J. H. (2003). Kin-based crews for interstellar multi-generational space travel. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, Ontario, Canada: Apogee Books.
39. O'Rourke, D. H. (2003). Genetic considerations in multi-generational space travel. In Y. Kondo, F. C. Bruhweiler, J. Moore, & C. Sheffield (Eds.), *Interstellar travel and multi-generation space ships*. Burlington, Ontario, Canada: Apogee Books.

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Epilogue

There are potentially three show-stoppers affecting humans traveling in space. The first deals with the effects of microgravity on human physiology, such as bone loss and muscle atrophy. Currently, exercising in space helps to slow down some of these effects, and people have been able to tolerate microgravity for up to 14 months. But it is difficult to predict how people will do in microgravity during expeditionary missions to the planets and stars that last much longer. One solution to this issue is to establish artificial gravity for brief periods of time in an on-board centrifuge, or by rotating the space vehicle around its own center of mass, or by rotating it around an external center in space between the astronauts vehicle and another vehicle several kilometers away and connected to it via high-strength tethers. Such solutions are theoretically doable but require further engineering developments and testing.

A second possible show-stopper has to do with exposure to radiation. During orbital missions, astronauts receive protection from particulate and wave radiation by the Earth's Van Allen belts, which shield them from excessive amounts of radiation in space. But leaving the near-Earth confines for interplanetary or interstellar destinations exposes space travelers to radiation from the Sun and to sources from deep space. To compensate, space vehicles need proper shielding from the effects of radiation. Such shielding adds cost to space ship construction, although creative and relatively inexpensive solutions have been proposed, such as using rocks or the crewmembers' stored water as a radiation shield. The big problem is the additional weight that a shielding system introduces, which adds mass and bulk to the ship, as well as fuel costs and design complexities. But again, radiation shielding is a doable activity, especially as low-weight materials are developed and engineering problems are solved.

The third possible show-stopper has been the subject matter of this book: the psychological hurdles that face a group of people confined for long periods of time on a space mission. Like microgravity and radiation, one hopes that the psychological, psychiatric, and interpersonal problems will be solved, especially for long-duration missions lasting years that will transport a crew to the planets of our Solar System and to exoplanets orbiting other star systems in deep space. Let's take a look at the big picture and explore how this can be done, using an expedition to Mars as an example.

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0_13

First of all, an incremental approach is warranted. Just like we needed to launch a vehicle to orbit Earth before we could think about orbiting the Moon, we need to examine the impact of psychosocial issues in space simulation environments on Earth that model the duration, activities, and vicissitudes of a planned space mission as realistically as possible. Since microgravity and real danger likely won't be present, such simulations can only approximate the actual mission. But an environment like an Antarctic base or a space simulator like the Mars 500 facility is a good first step. Following this, a simulation in space can occur. To prepare for an expedition to Mars, a stay in the International Space Station (ISS) could simulate the outbound and return phases of the mission, and an exploratory visit to a lunar base could simulate living on Mars by providing a partial Earth gravity, a solid natural surface, an essentially non-existent atmosphere, and increased radiation. Such a program would also simulate danger and the expectations and consciousness of crewmembers, their families, Mission Control personnel, space agency managers, political leaders, and the public of what it will be like during the actual mission.

Second, resources to properly conduct an actual Mars mission are needed. Adequate money and personnel are required for the selection, monitoring, support, and return of a space crew from a trip to the Red Planet. But these resources need to be stable for years, not changing with every political election and reprioritization with other activities competing for the same money. The US committed itself to a decade of appropriate and constant funding to reach the Moon, and its efforts were successful. This same successful process needs to be repeated for a Mars expedition, but on an international scale involving politicians and governments willing to make a long-term commitment. This commitment needs to include the selection of the crew, a training program for crewmembers and monitoring staff on Earth, support resources involving the best technology available, and realistic plans to recover and support the crew and their families throughout and after the mission. Sadly, in recent years planning for a Mars mission has been on again, off again, with the result that valuable time has been lost and start-up money has been wasted. In addition, personnel have left the space agencies in frustration, and successful engineering plans have been lost or ignored. This loss of continuity has resulted in a "reinventing the wheel" mentality, which is wasteful and demoralizing.

Third, there is a tendency to consider human factors subservient to engineering factors in planning a space mission. The crew is seen as just one of many components of the mission, and in some cases a less important component consisting of people "just going along for the ride." Leaders and managers need to realize that a Mars expedition hinges on human participation, and the crew is a critical component of a successful mission. Their psychological needs in terms of physical space, sustaining environment, and resources to assure their well-being need to be placed high on the list during the planning of the mission. This will take money and creative thinking in human factors engineering, but the result will be a mission that achieves its goals in a positive and successful manner. In addition, the taxpayers will be more involved with a mission that includes people, and having a crew successfully walk on this planet and return successfully to Earth will allow the public to vicariously live the experience with them.

Finally, since ambitious space missions are costly and complex, they likely will be multinational in scope. Cultural factors need to be addressed openly, not only within the space crew, but also with people in Mission Control who are supporting the mission from

different participating agencies. All aspects of culture need to be considered: national, organizational, and professional. In fact, engaging in a major new space venture such as an expedition to Mars will test our ability to cross cultural boundaries and interact internationally around a common goal, even more than we have done in constructing and operating the ISS. This will have spinoffs, not only for the mission itself, but also for international cooperation in general. People can learn that working in a diverse environment around a common goal can benefit everyone, not only in fund-sharing, but also in terms of the kinds of problem solving and creativity that differing points of view can provide. We must learn to cooperate around such a mission, and what we learn will help to lower barriers to solving other challenges that affect us as a species, such as climate change, poverty and hunger, and terrorism.

Space is the new frontier, and it is endless. Dealing with the psychological issues of future manned missions will be challenging but not insurmountable. We have come a long way in space, from cautious inroads beyond Earth's atmosphere, to the construction of giant orbiting facilities, to landing on the Moon. The next challenge will be to go further in establishing a presence in space in order to extend our reach to the planets in our Solar System and to exoplanets in other star systems. Human beings are key to this enterprise, and the psychological hurdles must be conquered one at a time until none are left. *Ad astra!*

Glossary

Ad astra Latin for "to the stars"
Asthenia An adjustment reaction to the conditions of space that has been identified by Russian flight surgeons as occurring in many of their cosmonauts. It manifests itself as fatigue, tiredness, loss of strength, low sensation threshold, unstable mood, and sleep disturbance. Its symptoms are similar to those seen in neurasthenia, a more severe neurotic condition
Autonomization A process of increasing egocentricity in members of a group living in an isolated and confined condition, such as in space
Autonomy The level of discretion and freedom an individual or team is given to perform tasks, including decision-making and problem solving
Cosmonaut The Russian term for an astronaut in the Russian Federal Space Agency
Displacement The directing outwardly of tension and other unpleasant emotions from a person in an isolated group to a person outside the group who is a safe target
Dysphoria A state of unease or dissatisfaction
Earth-out-of-view phenomenon The psychological ramifications of seeing Earth as an insignificant dot in space
Exoplanet A planet orbiting a star other than our Sun
GES A psychological test called the Group Environment Scale that measures the general interpersonal climate of a group of people along various dimensions (e.g., cohesion, leader support)
Groupthink The tendency of a group to strive for consensus at the cost of considering alternative courses of action
Habitable zone The distance from a star where the temperature is such that water on an orbiting planet can exist in liquid form
HTO vehicle A flying vehicle that takes off horizontally, like an airplane
ICE An isolated and confined environment. Examples include an Antarctic station during the winter-over period, a submersible space simulator, or an orbiting space station
Kuiper belt A flat ring in the outer Solar System in which reside the nuclei of short-period comets

N. Kanas, *Humans in Space*, Springer Praxis Books, DOI 10.1007/978-3-319-18869-0

Long-eye phenomenon In isolated groups living in the Antarctic, the term given to people who stare off into space and experience dissociation and even psychosis as a result of being excluded from the group

Microgravity The near-zero gravity condition found in space

MRAB A self-assessment test called the MiniCog Rapid Assessment Battery that has been developed to help crewmembers evaluate their cognitive functioning while in space

Oort cloud A spherical area in the outer Solar System in which reside the nuclei of long-period comets

POMS A psychological test called the Profile of Mood States that measures a person's emotions along various dimensions (e.g., tension–anxiety, depression–dejection)

Psychological closing The filtering of information that a space crew divulges to people on the outside

Salutogenesis The health-promoting, growth-enhancing effects of a challenging situation

Space adaptation syndrome The "space sickness" experienced by many astronauts as they adapt to microgravity during a space mission

Space tourism Space travel primarily made for recreational or leisure-time purposes and organized through private means

Spaceflight participant A non-astronaut participating in space tourism. Such a person often is engaged in space-related business or scientific activity during the mission

Stress The effects of a stressor on someone. This can be physical, psychological, or interpersonal

Stressor A characteristic of the environment, both physical and psychological, that impacts on someone

Third quarter phenomenon An increase in emotional problems experienced by some people working in an isolated and confined environment after the halfway point of their mission

VIIP Visual impairment and increased intracranial pressure, as well as ocular changes, that have been found in many astronauts returning from space. The syndrome is thought to be caused by microgravity and other stressors of space travel

VTO vehicle A flying vehicle that takes off vertically, like a rocket

WES A psychological test called the Work Environment Scale that measures the work-related interpersonal climate of a group of people along various dimensions (e.g., work pressure, supervisor support)

WinSCAT A self-assessment test called the Spaceflight Cognitive Assessment Tool for Windows that has been developed and implemented by NASA to help crewmembers evaluate their cognitive functioning while in space

Zeitgeber An environmental cue (such as light) that synchronizes an organism's biological rhythms to a period of time, such as Earth's 24-h day–night cycle

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